4 CHARACTERIZATION OF BIOLOGICAL RESOURCES

This section highlights the overall results of biological sampling conducted at first- through third-order, non-tidal streams sampled in the statewide 1995-1997 Maryland Biological Stream Survey (MBSS or the Survey). The abundance and diversity of fish species are presented, including a special focus on gamefish and an evaluation of fish health reflected by observed anomalies. This section also includes general information on benthic macroinvertebrates, amphibians and reptiles, mussels, and aquatic vegetation.

The probability-based sampling design of the Survey allows parameters of interest, such as fish abundance, to be estimated on either a basinwide or statewide basis. This section reports statewide estimates based on sites sampled in the three-year Survey. Selected basin results have been included as highlights to the discussion. Other basin-specific estimates are reported in separate reports for the basins sampled in 1995 (Roth et al. 1997, Appendix F), 1996 (Roth et al. 1998, Appendix E), and 1997 (Roth et al. 1999). The Survey was designed so that the number of sites is proportional to the number of stream miles (by stream order) in a basin (Appendix B, Tables B-1 and B-2). Although a sufficient number of sites were sampled per basin, basin estimates from the smaller basins (including the Bush, Elk, Choptank, and Nanticoke/Wicomico) are more sensitive to the influence of extreme values at one or two sites compared to larger basins. Here, and throughout the report, standard errors are provided as a measure of the variability of the estimates.

4.1 FISH

4.1.1 Fish Abundance, Biomass, and Species Richness

Throughout the three years of core MBSS sampling using the stratified random sampling design, 83 fish species were collected at the 905 segments sampled during the summer; two additional species were collected at supplemental qualitative electrofishing sites. The total number of species collected was 85 (Table 4-1; Appendix C, Table C-1). These represent 72% of the total number of freshwater fish species occurring in Maryland (Lee et al. 1981). A list of freshwater fish species historically or currently known to occur in Maryland, but not recorded in the Survey, is included in Appendix C, Table C-2.

Most species were collected in the Patuxent basin (57 species at core MBSS and supplemental sites combined). The lowest number occurred in the Youghiogheny and Nanticoke/Wicomico basins (28 species). The total number of species in each of the other basins ranged from 29 to 54 (Table 4-2).

Three species had widespread distributions, occurring in all basins sampled. These species, all in the family Centrarchidae, are the bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), and pumpkinseed (*Lepomis gibbosus)*. Five additional species occurred in every basin but one. Six species occurred in only one basin: the longnose gar (*Lepisosteus osseus*), striped shiner (*Luxilus chrysocephalus*), shorthead redhorse (*Moxostoma macrolepidotum*), flier (*Centrarchus macropterus*), johnny darter (*Etheostoma nigrum*), and stripeback darter (*Percina notogramma*). Two species were found only in non-randomly selected supplemental sampling sites: the Atlantic menhaden (*Brevoortia tyrannus*) and banded darter (*Etheostoma zonale*).

Among the fish collected in the Survey were several occurrences not often reported in Maryland. Checkered sculpin (*Cottus* sp. nov.), an undescribed species endemic to Maryland, were found at one second-order site in the Middle Potomac basin and in several first- and second-order sites in the Upper Potomac basin. Cutthroat trout (*Oncorhynchus clarki*), native to the Rocky Mountains but recently introduced into Maryland, were found at three third-order sites in the North Branch Potomac basin and one second-order site in the Patapsco basin. In addition, six species listed by the Maryland DNR Wildlife and Heritage Division as rare were collected: mud sunfish (*Acantharcus pomotis*), ironcolor shiner (*Notropis chalybaeus*), logperch (*Percina caprodes*), flier, glassy darter (*Etheostoma vitreum*), and stripeback darter. See Chapter 12 for further discussion of rare species.

The number of species per 75-m segment varied throughout the basins (Figure 4-1, Table 4-2). Mean per-segment species richness was generally highest in the basins of the eastern and central portions of the state, with a high of 12.8 in the Elk basin. In comparison, lower species richness was reported in the higher-elevation streams of western Maryland, where the mean number of fish species per segment was 3.7 in the North Branch Potomac basin,

Table 4-1. Fish species found at core MBSS and Supplemental sites, by basin

Fish Family	Fish Species	Notes	Youghiogheny	North Branch Potomac	Upper Potomac	Middle Potomac	Potomac Washington Metro	Lower Potomac	Patuxent	West Chesapeake	Patapsco	Gunpowder	Bush	Susquehanna	Elk	Chester	Choptank	Nanticoke/Wicomico	Pocomoke
Lampreys: Petromyzontidae	American brook lamprey						X		X										
	Least brook lamprey						X	X	X	X	X		X		X	X	X	X	X
	Sea lamprey	d					X	X	X			X	X	X	X	X			
Gars: Lepisosteidae	Longnose gar																		X
Freshwater Eels: Anguillidae	American eel			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Herrings: Clupeidae	Atlantic menhaden															S			
	Gizzard shad								X	X									
Pikes: Esocidae	Chain pickerel	iy, g	X		X		X	X	X	X	X				X	X	X	X	X
	Redfin pickerel	iy, g	X				X	X	X	X	X		S		X	X	X	X	X
Mudminnows: Umbridae	Eastern mudminnow						X	X	X	X	X		X		X	X	X	X	X
Minnows: Cyprinidae	Blacknose dace		X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	Bluntnose minnow		X	X	X	X	X		X		X	X	X	X					
	Central stoneroller		X	X	X	X	X		X		X	X		X					
	Comely shiner				S	X	X				X		X				X		
	Common carp	i		S	X	X	X	S			X		S	X	S				
	Common shiner		X	X	X	X	X	X	X		X	X	X	X	X				
	Creek chub		X	X	X	X	X	X	X		X	X	X	X	X				
	Cutlips minnow			X	X	X	X		X		X	X	X	X	X				
	Eastern silvery minnow					X	X	X	S				X		X				
	Fallfish			X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	Fathead minnow	i	X		X	X	X	X	X		X	X							
	Golden shiner		X	S	S	X	X	X	X	X	X		S	X	X	X	X	X	X
	Goldfish	i			S		X	S		X	X		X						
	Ironcolor shiner							X									X		
	Longnose dace		X	X	X	X	X		X		X	X	X	X	X				
	Pearl dace				X	X													
	River chub		X	X	X	X	X		X		X	X	X	X	X				
	Rosyface shiner			S	S	X					X		X	X	X				
	Rosyside dace			X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	Satinfin shiner					X	X	X	X	X	X	X	X	X	X	X	X		X
	Silverjaw minnow					X	X				X	S							

Table 4-1. Cont'd

Fish Family	Fish Species	Notes	Youghiogheny	North Branch Potomac	Upper Potomac	Middle Potomac	Potomac Washington Metro	Lower Potomac	Patuxent	West Chesapeake	Patapsco	Gunpowder	Bush	Susquehanna	Elk	Chester	Choptank	Nanticoke/Wicomico	Pocomoke
Minnows: Cyprinidae (cont'd)	Spotfin shiner			X	X	X	X				X			X					
	Spottail shiner			S	X	X	X	X	X	X	X	S	S	X	X	X		S	
	Striped shiner		X																
	Swallowtail shiner					X	X	X	X	X	X	X	X	X	X	X	X		X
Suckers: Catostomidae	Creek chubsucker			X	X	X	X	X	X	X	X		X		S	X	X	X	X
	Golden redhorse			X	S	S													
	Northern hogsucker		X	X	X	X	X		X		X	X	X	X	X				
	Shorthead redhorse								X										
	White sucker		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Catfishes: Ictaluridae	Brown bullhead		X	X		X	X	X	X	X	X	S	X	X	S	X	X	X	X
	Channel catfish	ic			S	X			S					S					X
	Margined madtom	iy		X	S	X	X	X	X		X	X	X	X	X	X	X	X	X
	Tadpole madtom							X	X						S	X	X	X	X
	White catfish	iy					X		S							S			X
	Yellow bullhead		X	X	X	X	X	X	X		X	X		X		S	X	X	X
Trouts: Salmonidae	Brook trout	g	X	X	S	X					X	X		X					
	Brown trout	g,i	X	X	X	X	X		X		X	X		X	X				
	Cutthroat trout	g,i		X	S						X								
	Rainbow trout	g,i	X	X	X	X	X		X	X	X	X	X	S	X				
Pirate Perches: Aphredoderidae	Pirate perch							X	X							X	X	X	X
Killifishes: Fundulidae	Banded killifish				S	X	X	X	S		X			X	X	X		S	
	Mummichog						X	S	X	X	X	S				X			X
Livebearers: Poeciliidae	Mosquitofish						X	X	X	X	X	S				S		X	X
Sculpins: Cottidae	Checkered sculpin				X	X													
	Mottled sculpin		X	X	X	X	X		X		X	X	X	X	X			X	
	Potomac sculpin			X	X	X	X												
Striped Basses: Moronidae	Striped bass	g							S		X				X				
	White perch					S	X	S	S					S	S	X		S	X
Sunfishes: Centrarchidae	Banded sunfish									X			S						X
	Black crappie	ic			X			X	X	X	X					X	X	X	X
	Bluegill	ic	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 4-1. Cont'd

Fish Family	Fish Species	Notes	Youghiogheny	North Branch Potomac	Upper Potomac	Middle Potomac	Potomac Washington Metro	Lower Potomac	Patuxent	West Chesapeake	Patapsco	Gunpowder	Bush	Susquehanna	Elk	Chester	Choptank	Nanticoke/Wicomico	Pocomoke
Sunfishes: Centrarchidae (cont'd)	Bluespotted sunfish						X	X	X		X				S	X	X	X	X
	Flier							X											
	Green sunfish	ic	X	X	X	X	X	X	X	X	X	X	X	X		X			
	Largemouth bass	ic, g	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Longear sunfish	ic			S	X						X							
	Mud sunfish															S	X	X	X
	Pumpkinseed	iy	X	X	X	X	X	X	X	X	X	S	X	X	X	X	X	X	X
	Redbreast sunfish	iy		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Rock bass	ic	X	X	X	X	X				X	X		X					
	Smallmouth bass	ic,g	X	X	X	X	X		X		X	X	X	X	X				
	Warmouth							X	X										
Perches: Percidae	Banded darter	i												S					
	Fantail darter			X	X	X	X					X							
	Glassy darter								X									X	X
	Greenside darter			X	X	X	X												
	Johnny darter		X																
	Logperch													X	X				
	Rainbow darter			X	S														
	Shield darter								X			X		X			X		
	Stripeback darter								X										
	Swamp darter							X								X	X	X	X
	Tessellated darter			S	S	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Yellow perch	iy	X	X				X	X	X	X			S	S	X	X	X	X

Notes:

X - Indicates that the species was caught at a random MBSS site
S - Indicates that the species was caught at a non-random supplemental site
d - Diadromous
g - Gamefish
i - Introduced
ic - Introduced to the Chesapeake drainage only
iy - Introduced to the Youghiogheny drainage only

Table 4-2. Fish species richness for basins sampled in the 1995-1997 MBSS

	Number of Species Collected in Basin*	Mean Number of Species per Segment	Standard Error
Basin			
Youghiogheny	28	5.2	0.7
North Branch Potomac	41	3.7	0.4
Upper Potomac	49	4.5	0.5
Middle Potomac	50	8.6	0.7
Potomac Washington Metro	54	9.3	0.8
Lower Potomac	43	8.1	1.0
Patuxent	57	8.4	0.6
West Chesapeake	29	3.7	0.8
Patapsco	52	8.6	0.8
Gunpowder	39	8.3	0.9
Bush	38	11.0	1.9
Susquehanna	43	9.6	1.1
Elk	42	12.8	2.6
Chester	37	8.6	1.4
Choptank	30	12.4	2.3
Nanticoke/Wicomico	28	8.4	1.8
Pocomoke	32	10.7	2.2
Stream Order			
1	57	5.8	1.0
2	75	10.9	1.3
3	79	15.0	1.6
All	85	7.7	1.0

* Includes species collected at core MBSS and supplemental sites

reflecting natural differences due to geography and stream size, as well as impacts of acid mine drainage. As would be expected, species richness increased with stream order across all basins (Figure 4-2), with an average of 5.8 fish species per segment for first-order streams, 10.9 for second-order, and 15.0 for third-order streams.

Statewide density and abundance estimates are presented for each game and nongame fish species (Appendix E, Tables E-3 and E-4). The total catch from two electrofishing passes was used along with the total number of stream miles in the basin (by stream order) to estimate density of each species as the number of individuals per stream mile. Raw densities were then adjusted for the capture efficiency of the double-pass electrofishing method (Heimbuch et al. 1997). Adjusted densities were used to estimate adjusted total abundance, the number of individuals per basin, for each species. All abundance values reported here have been adjusted for capture efficiency.

Statewide, the most abundant stream fishes were (1) blacknose dace (*Rhinichthys atratulus*), estimated at 1,970

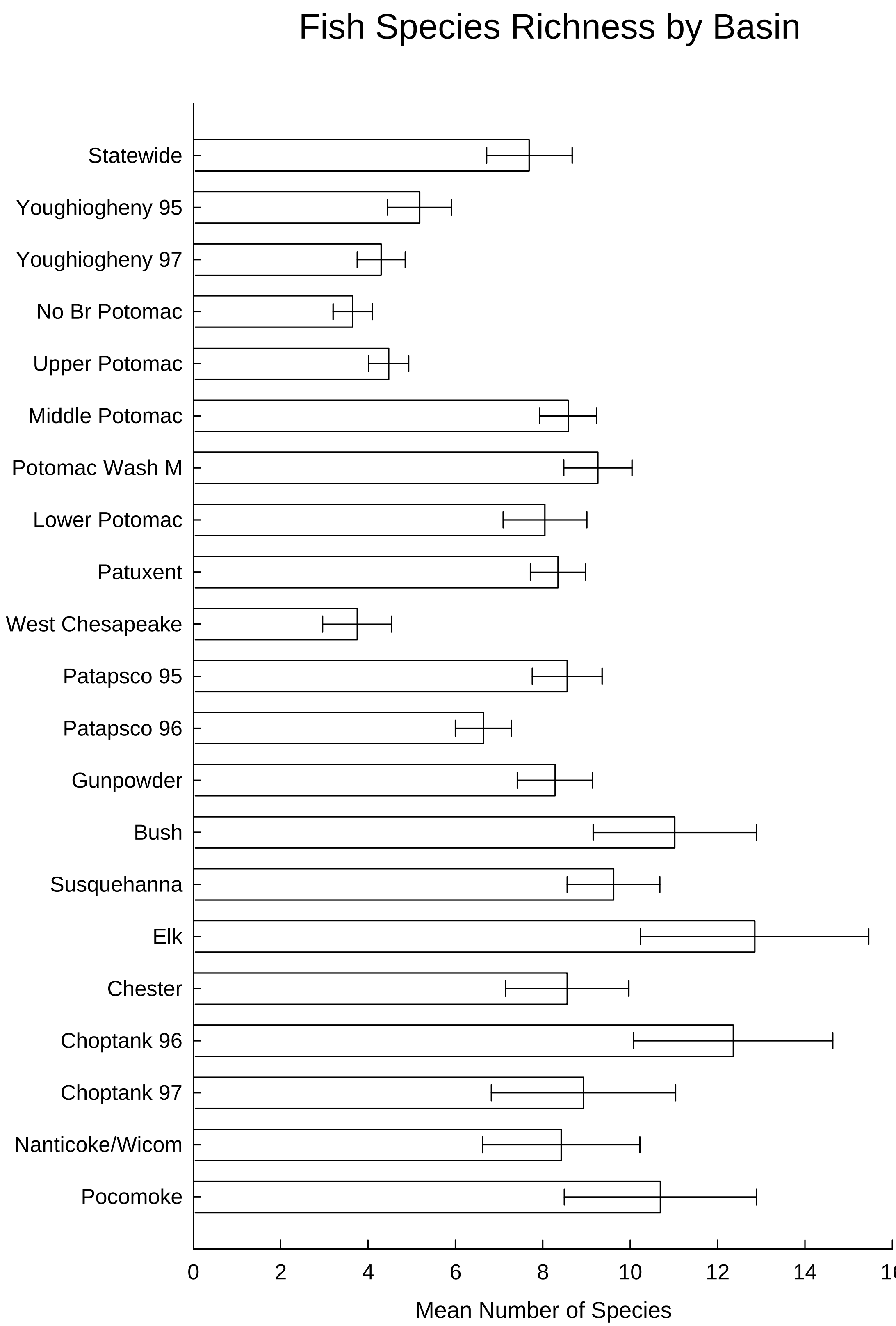


Figure 4-1. Per-segment fish species richness (mean number of species per 75-m segment), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

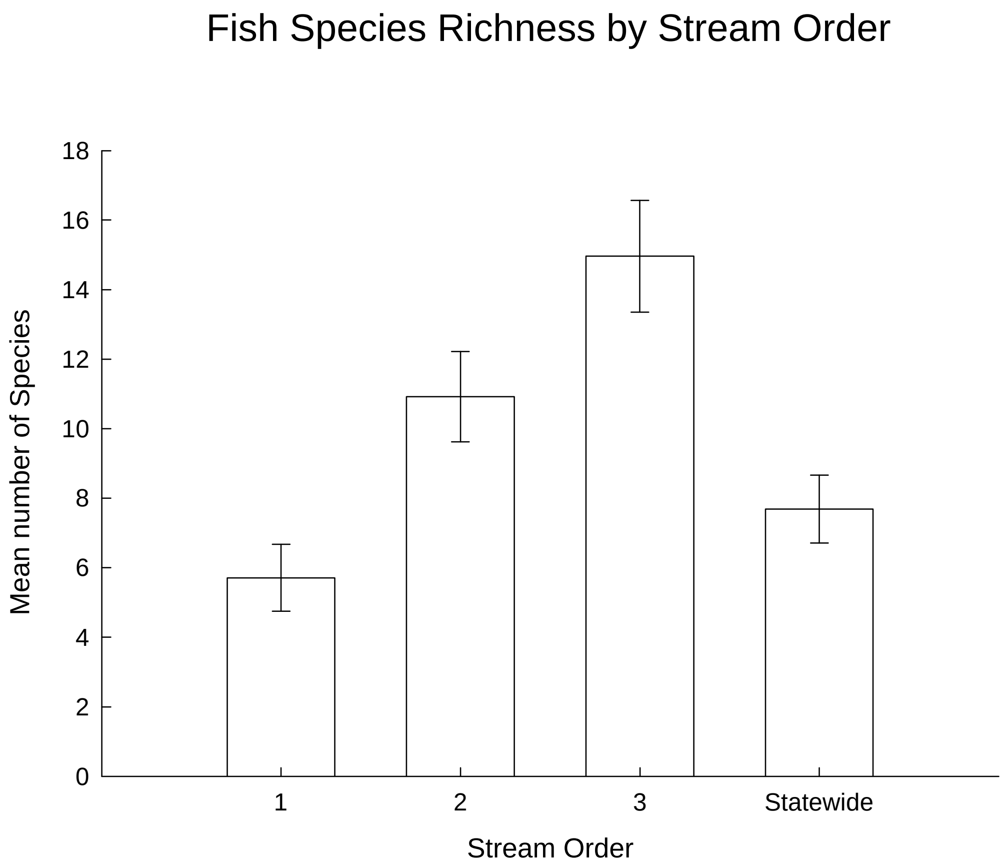


Figure 4-2. Per-segment fish species richness (mean number of species per 75-m segment), by stream order, for the 1995-1997 MBSS. Error bars signify ±1 standard error.

individuals per stream mile and nearly 11.6 million individuals statewide, and (2) mottled sculpin (*Cottus bairdi*), estimated at 1,370 individuals per stream mile and nearly 8.1 million individuals statewide. The most abundant gamefish species were (1) brook trout (*Salvelinus fontinalis*), with an estimated 54 individuals per stream mile and nearly 318,000 individuals statewide and (2) largemouth bass, with an estimated 53 individuals per stream mile and more than 311,000 individuals statewide.

Combining all species, mean fish density was estimated at 10,325 individuals per stream mile. Densities were also compared across all 17 basins and three stream orders (Figures 4-3 and 4-4; Table 4-3). Density was lowest in the North Branch Potomac, with an estimated 2,633 fish per stream mile. Density estimates in other basins ranged from 3,299 to 15,099 fish per stream mile. Densities were higher in second- and third- order streams (16,556 and 22,040 individuals per stream mile, respectively), and lower in first-order streams (6,821 individuals per stream mile).

Statewide, an estimated 4% of stream miles had no fish. Because many streams that drain small watersheds may naturally contain no fish, this estimate excluded stream miles located in watersheds of less than 300 acres (Roth et al. 1998; Figure 4-5). Seven basins contain stream miles with no fish in watersheds that are greater than 300 acres: the Youghiogheny (1997 sampling), North Branch Potomac, Upper Potomac, Middle Potomac, Patapsco (1996 sampling), Chester, and Pocomoke basins.

Fish biomass estimates (kilograms per stream mile) were derived from the aggregate weights of game and nongame fish species. Because adjustment for capture efficiency depends on data for individual species, no such adjustment was made for biomass estimates. To accurately calculate

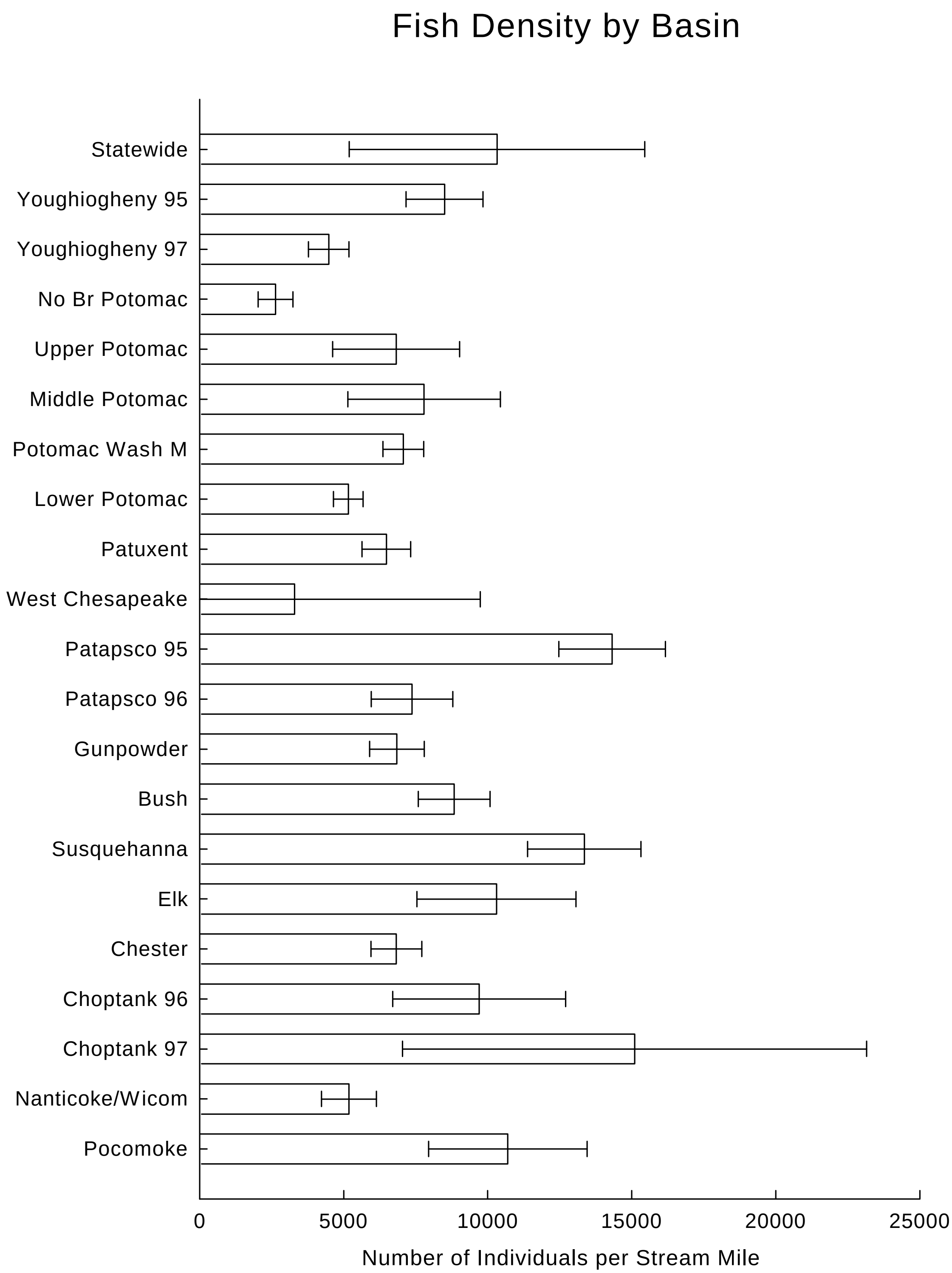


Figure 4-3. Fish density (number of individuals per stream mile), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error. Density estimates are adjusted for capture efficiency.

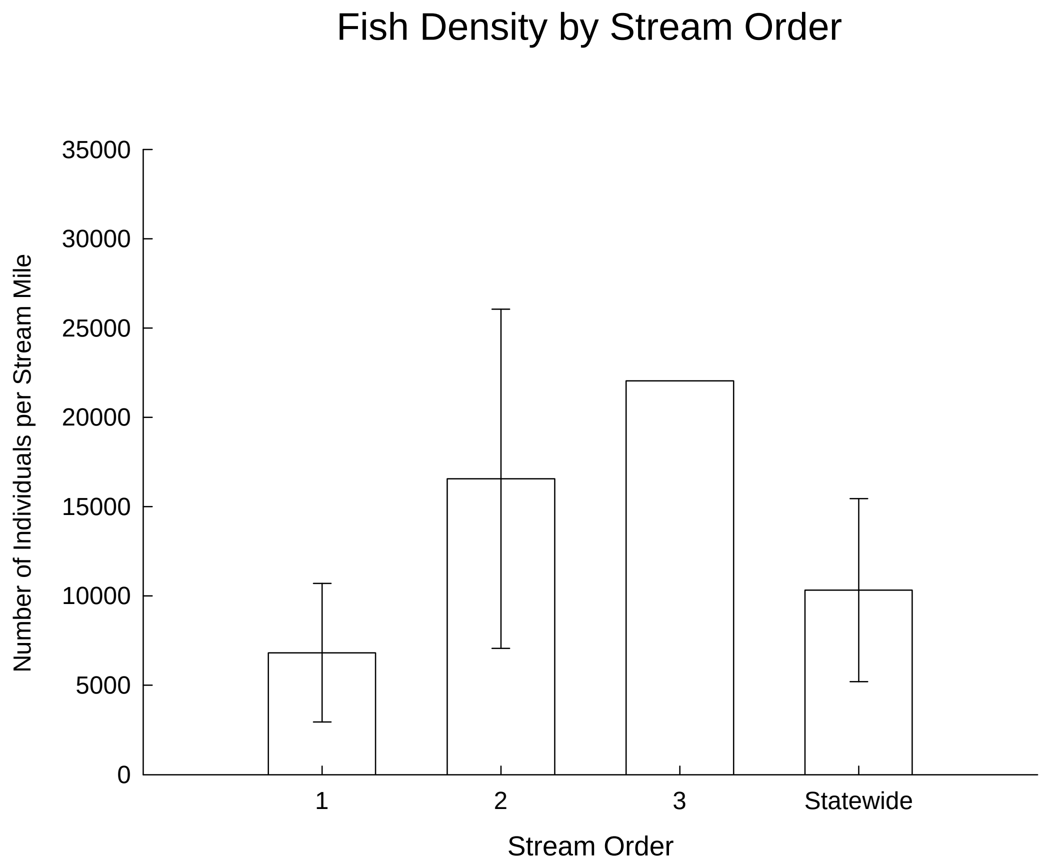


Figure 4-4. Fish density (number of individuals per stream mile) by stream order, for the 1995-1997 MBSS. Error bars signify ±1 standard error (lack of error bars indicate that variance is statistically undefined). Density estimates are adjusted for capture efficiency.

biomass adjusted for capture efficiency, actual biomass would need to be measured for each species individually. Size selectivity of the electrofishing gear may also bias biomass estimates.

Statewide, biomass was approximately 44.2 kg/stream mile. Biomass estimates ranged from about 18.0 kg per stream mile in the North Branch Potomac basin to 119 kg per stream mile in the Elk basin (Figure 4-6, Table 4-4). As would be expected, mean biomass was greater in second and third order streams (about 73.8 and 125.0 kg per stream mile, respectively) than in first order streams (about 24.1 kg per stream mile; Table 4-4).

4.1.2 Gamefish

The distributions of gamefish species varied across the state, as would be expected given physiographic differences in aquatic habitat (Table 4-1). Largemouth bass had the most widespread distribution, occurring in all basins. Smallmouth bass (*Micropterus dolomieu*) were present in 11 of the sampled basins. Striped bass (*Morone saxatilis*) were found at three Coastal Plain sites. Brook trout were found in seven of the basins; brown trout (*Salmo trutta*) were more widespread, occurring in ten basins. Rainbow trout (*Oncorhynchus mykiss*), a widely stocked species, were found in small numbers in 12 basins, while a few cutthroat trout (a recent introduction to Maryland) were found in the North Branch Potomac, Upper Potomac, and Patapsco basins.

The brook trout is an important native gamefish in Maryland streams (the other gamefish discussed above are introduced throughout most of their range in Maryland). Differences in density of brook trout were detected among basins and across stream orders (Figures 4-7 and 4-8). Statewide, the estimated density of brook trout is 54 individuals per stream mile. The 1997 sampling of the Youghiogheny basin had the greatest number of brook trout

Table 4-3. Estimated density (number of individuals per stream mile) for all fish (nongame fish and gamefish), for basins sampled in the 1995-1997 MBSS. Densities are adjusted for capture efficiency.

	Total Fish Density	Standard Error	Nongame Fish Density	Standard Error	Gamefish Density	Standard Error
Basin						
Youghiogheny 1995	8501.5	1336.2	8325.9	1339.6	175.6	53.3
Youghiogheny 1997	4478.3	702.9	4062.0	710.1	416.3	91.0
North Branch Potomac	2632.9	606.0	2539.4	607.5	93.4	27.9
Upper Potomac	6823.7	2204.0	6798.4	2203.6	25.3	7.9
Middle Potomac	7790.4	2648.1	7759.9	2647.9	30.4	12.5
Potomac Washington Metro	7073.3	710.0	7059.5	708.0	13.8	7.2
Lower Potomac	5158.8	517.0	5106.4	516.3	52.4	28.5
Patuxent	6481.1	845.9	6371.9	849.2	109.3	61.9
West Chesapeake	3299.0	6444.4	3155.5	6442.0	143.4	139.4
Patapsco 1995	14318.9	1849.5	14176.8	1850.1	142.1	47.5
Patapsco 1996	7372.3	1416.6	7188.6	1349.6	183.7	439.6
Gunpowder	6845.4	947.8	6581.3	951.4	264.0	68.7
Bush	8833.8	1246.1	8797.4	1247.4	36.0	17.4
Susquehanna	13353.0	1962.8	13072.7	1947.3	280.4	121.2
Elk	10303.9	2761.7	10231.7	2767.2	72.2	31.6
Chester	6830.2	883.1	6577.2	786.4	253.1	284.4
Choptank 1996	9706.4	3001.0	9660.0	3007.8	46.4	21.0
Choptank 1997	15099.2	8054.4	14910.3	8053.6	188.9	79.6
Nanticoke/Wicomico	5184.0	953.7	5152.6	958.3	31.5	39.8
Pocomoke	10698.6	2751.5	10694.4	2751.4	4.1	1.7
Stream Order						
1	6820.6	3870.7	6718.4	3815.4	102.2	62.7
2	16555.5	9500	16345.1	9590.1	201.2	121.1
3	22040.2	*	21601.2	*	438.6	*
Statewide	10324.9	5127.9	10169.5	5055.1	155.4	83.6

*Variance statistically undefined

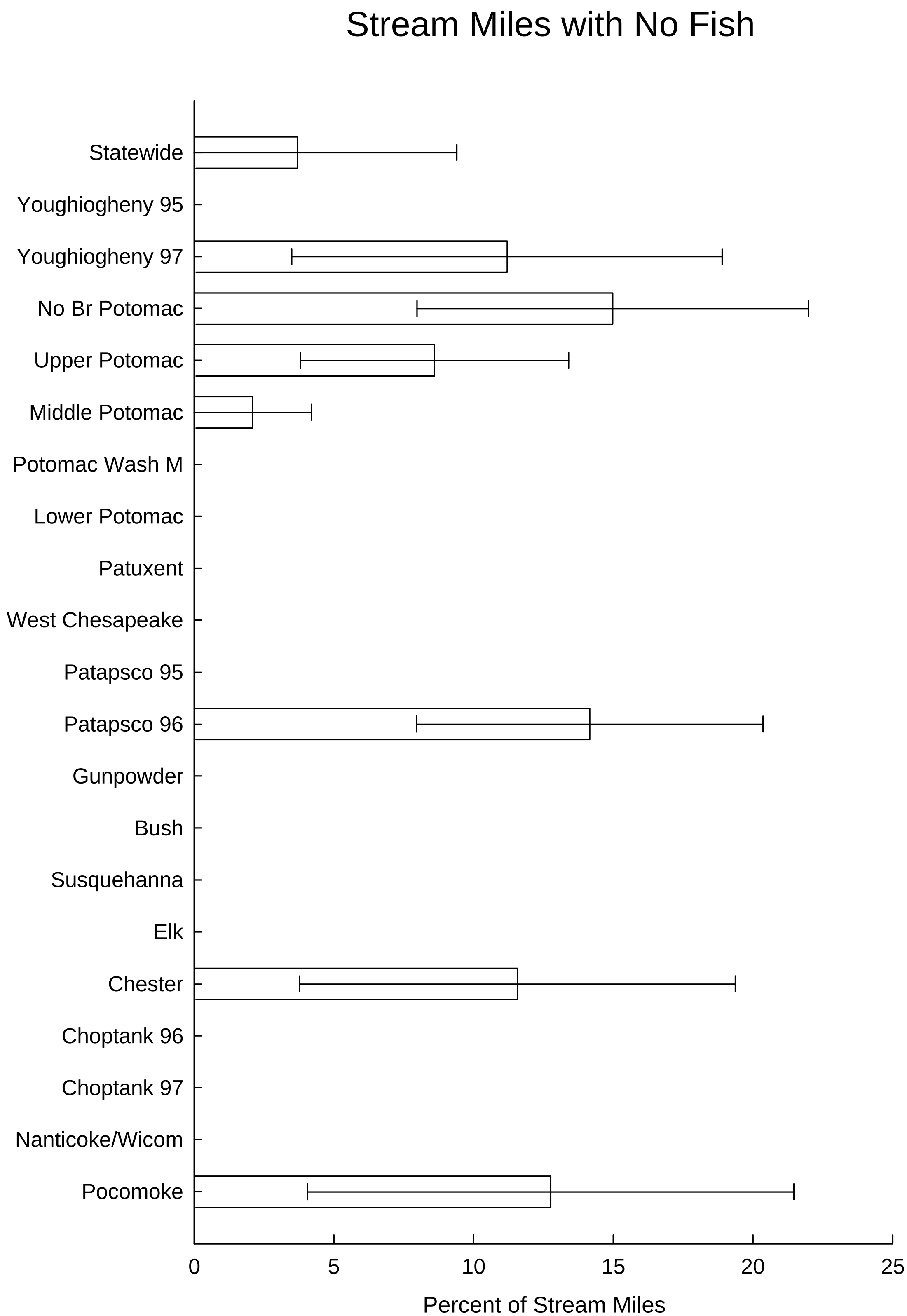


Figure 4-5. Estimated percentage of stream miles with no fish, statewide and for basins sampled in the 1995-1997 MBSS. Sites with watersheds < 300 acres were excluded from these estimates. Error bars signify ±1 standard error.

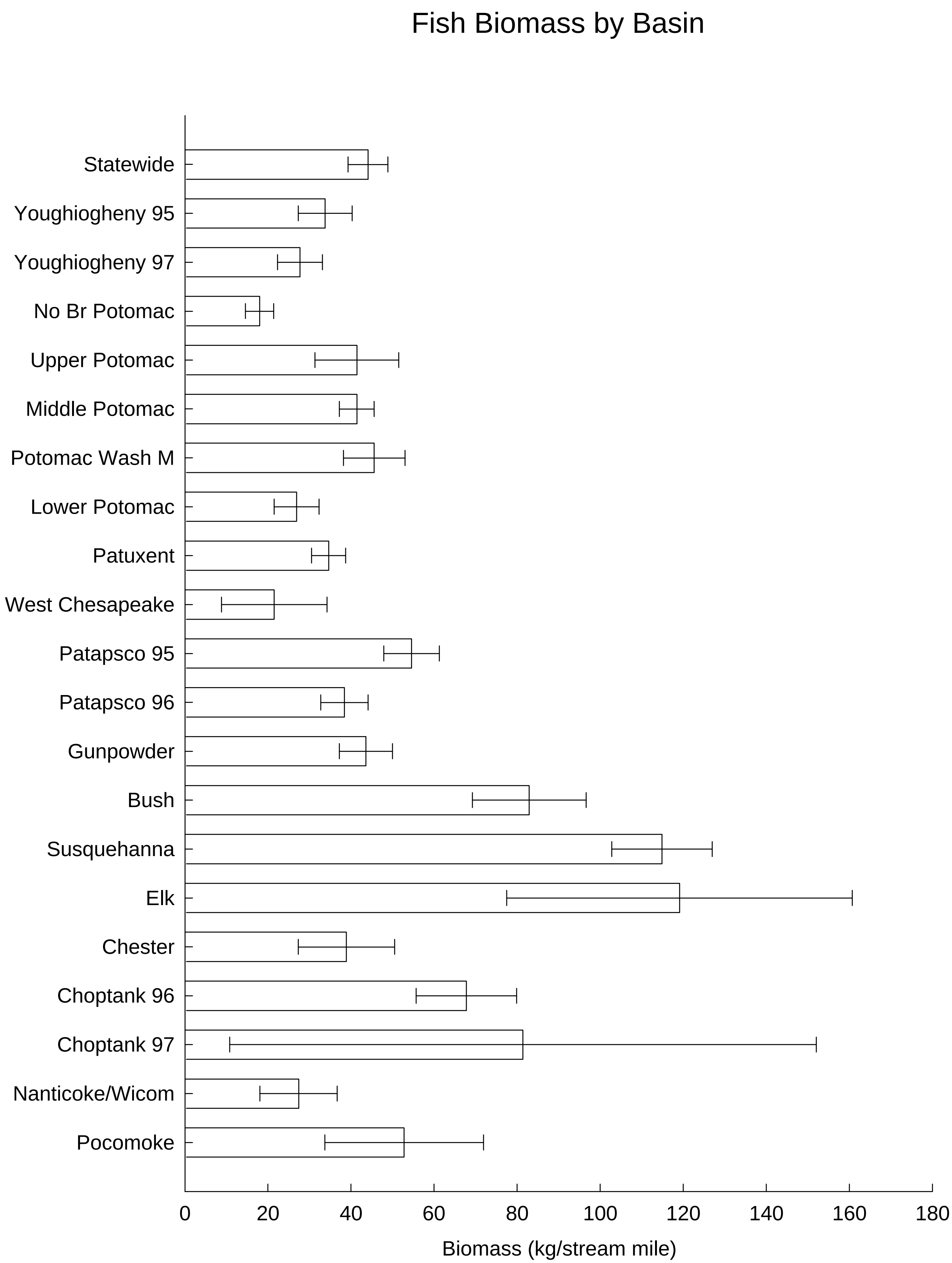


Figure 4-6. Fish biomass (kg per stream mile), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error. Biomass estimates are not adjusted for capture efficiency.

Table 4-4. Estimated biomass (kg/stream mile) for all fish (nongame fish, and gamefish), for basins sampled in the 1995-1997 MBSS. Estimates are not adjusted for capture efficiency.

	Total Fish Biomass	Standard Error	Nongame Fish Biomass	Standard Error	Gamefish Biomass	Standard Error
Basin						
Youghiogheny 1995	33.8	6.5	29.0	6.0	4.8	2.7
Youghiogheny 1997	27.7	5.4	19.9	4.6	7.8	2.7
North Branch Potomac	18.0	3.4	13.4	3.1	4.6	1.5
Upper Potomac	41.3	10.1	39.3	9.7	2.1	0.6
Middle Potomac	41.4	4.2	40.1	4.1	1.3	0.4
Potomac Washington Metro	45.6	7.4	45.0	7.4	0.7	0.3
Lower Potomac	27.0	5.4	25.5	5.1	1.5	1.0
Patuxent	34.6	4.1	32.7	4.0	2.0	0.7
West Chesapeake	21.5	16.7	21.1	16.4	0.4	0.3
Patapsco 1995	54.6	6.7	50.2	6.4	4.4	1.3
Patapsco 1996	38.4	5.7	35.7	5.4	2.7	0.7
Gunpowder	43.6	6.4	38.8	6.3	4.8	1.8
Bush	82.9	13.7	80.8	13.3	2.0	1.4
Susquehanna	114.9	19.1	108.5	18.7	6.3	2.6
Elk	119.1	41.6	103.7	36.9	15.4	23.8
Chester	38.9	11.6	36.4	11.3	2.5	10.2
Choptank 1996	67.8	12.1	65.8	12.3	2.1	1.8
Choptank 1997	81.5	70.6	75.6	61.0	5.9	9.8
Nanticoke/Wicomico	27.5	9.3	25.0	8.2	2.5	1.9
Pocomoke	52.9	19.1	52.7	19.1	0.2	0.2
Stream Order						
1	24.1	6.2	22.5	5.4	1.6	1.9
2	73.8	13.4	69.5	13.4	4.3	2.4
3	124.7	23.1	113.6	23.2	11.0	5.2
Statewide	44.2	4.8	411.9	4.9	3.1	1.6

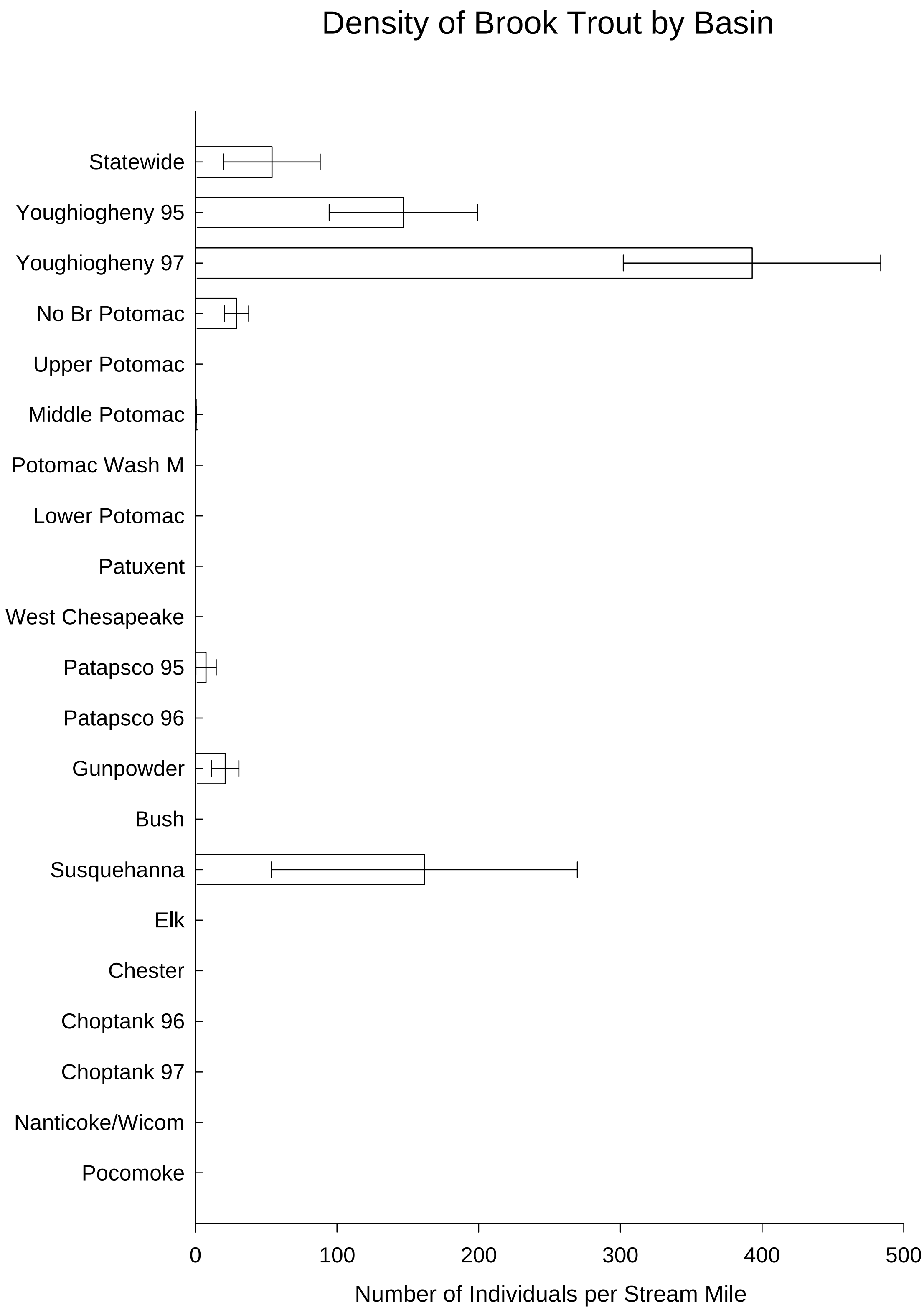


Figure 4-7. Density (number of individuals per stream mile) of brook trout (*Salvelinus fontinalis*), statewide and for the basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error. Density estimates are adjusted for capture efficiency.

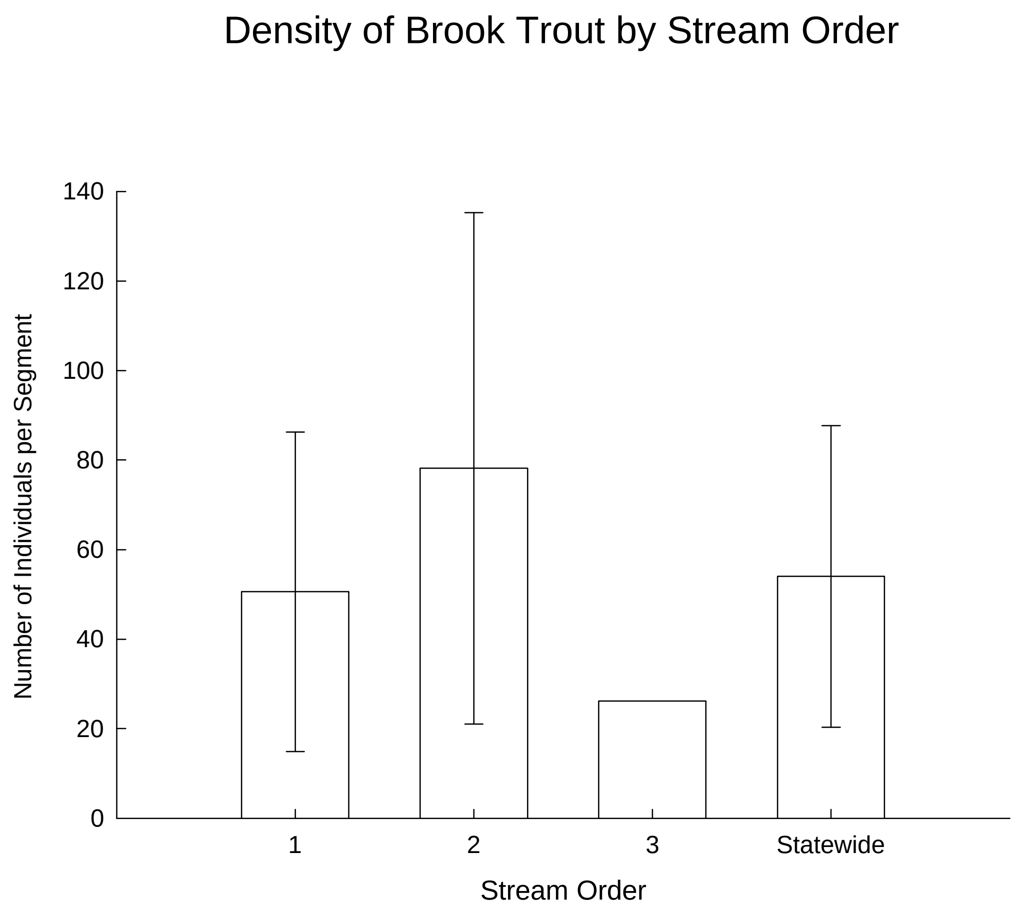


Figure 4-8. Density (number of individuals per stream mile) of brook trout (*Salvelinus fontinalis*), by stream order for the basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error (lack of error bars indicate that variance is statistically undefined). Density estimates are adjusted for capture efficiency.

individuals per stream mile (393 individuals per stream mile). The other basins that contained brook trout were: the Youghiogheny (1995 sampling), North Branch Potomac, Patapsco (1995 sampling), Middle Potomac, Gunpowder, and Susquehanna. Brook trout density also varied across stream orders, with third-order streams having fewer brook trout individuals per stream mile (26) than both first- and second- order streams (51 and 78, respectively).

The density, abundance, and biomass of combined gamefish species were calculated from MBSS data. Total gamefish density (Figures 4-9 and 4-10; Table 4-3) was greatest in the Youghiogheny (1997 sampling) and Susquehanna basins, where brook trout and brown trout were the dominant game species. The Gunpowder basin, dominated by brook trout and brown trout, and the Chester basin, dominated by largemouth bass, were also among the basins with greatest gamefish density. Over all basins and stream orders, the mean density of gamefish was 155 individuals per stream mile, with the greatest density in third-order streams (439 individuals per stream mile). Although first-order streams had a lower mean density of gamefish (102 individuals per stream mile), the estimated total abundance of gamefish inhabiting first-order streams is actually greater than that of third-order streams, given the greater total length of lower order streams throughout the basins. Aggregate gamefish biomass exhibited a slightly different pattern than did gamefish density (Figure 4-11, Table 4-4). The highest gamefish biomass occurred in the Elk basin and third-order streams had far greater gamefish biomass than did smaller streams, reflecting the populations of larger adult fish present in third-order streams. Many of the gamefish captured by the Survey were below legal or catchable size limits, as might be expected given the number of small streams sampled.

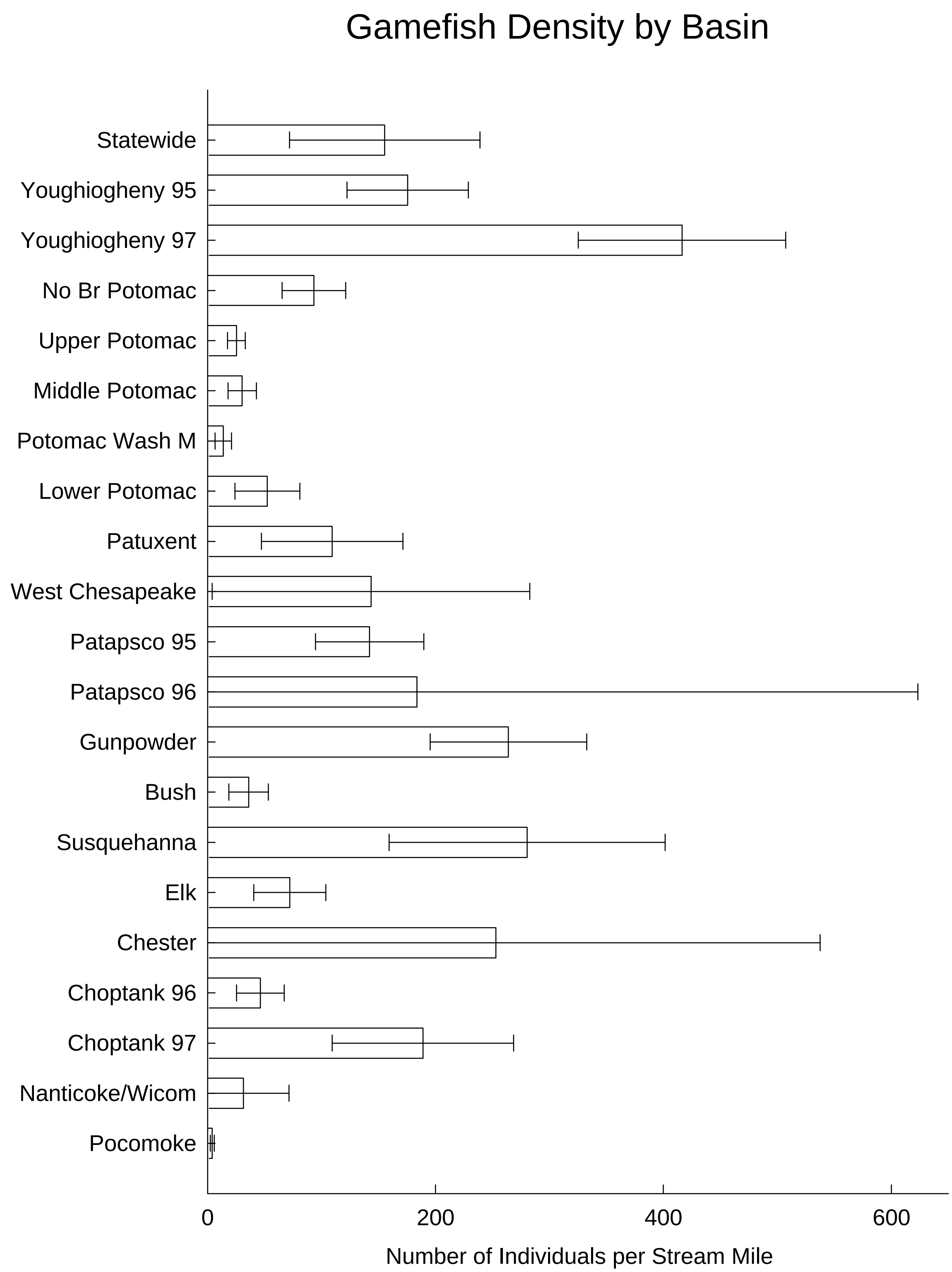


Figure 4-9. Total gamefish density (number of individuals per stream mile), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error. Density estimates are adjusted for capture efficiency.

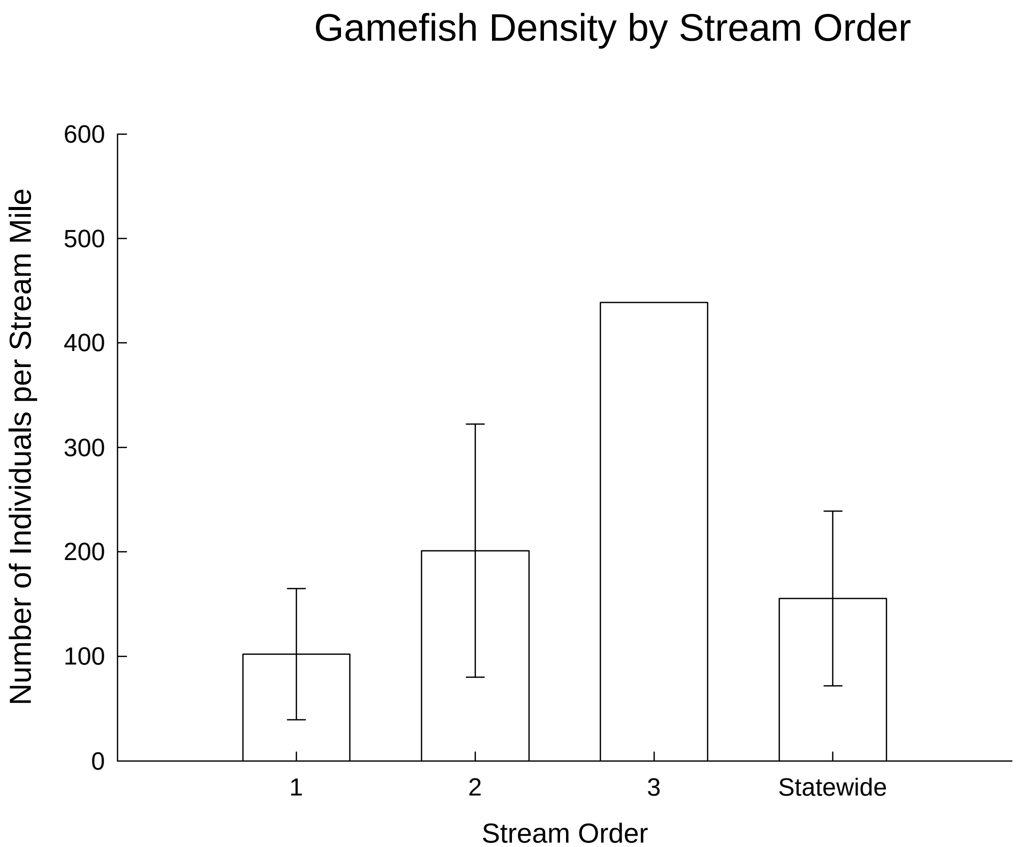


Figure 4-10. Total gamefish density (number of individuals per stream mile), by stream order for the 1995-1997 MBSS. Error bars signify ±1 standard error (lack of error bars indicate that variance is statistically undefined). Density estimates are adjusted for capture efficiency.

Using measured lengths of individual gamefish, separate estimates were made of the abundance of legal-sized or otherwise harvestable gamefish. Minimum sizes used to designate harvestable gamefish were the statewide size limits of 12” for largemouth and smallmouth bass, 14” for chain pickerel, and 18" for striped bass. Harvestable trout were defined as those 6” or greater. Across all basins, brook trout were estimated to be the most abundant harvestable-size gamefish in first- through third-order streams, followed by brown trout (Appendix E, Table E-3). Population estimates of harvestable-sized gamefish in low-order streams statewide were: 55,160 brook trout, 43,882 brown trout, 6,987 rainbow trout, 4,928 chain pickerel, and 4,530 largemouth bass, with smaller numbers of cutthroat trout and smallmouth bass. No harvestable size striped bass (a species abundant in tidal waters) were found in the streams surveyed. The abundance of harvestable-size gamefish was greatest in the Gunpowder basin, with an estimated 23,565 harvestable-size fish (Figure 4-12).

4.1.3 Individual Health of Fish

The health of stream fishes was assessed through the observation of specific anomalies on individual game and nongame fish. At each segment all gamefish and up to 100 individuals of each nongame fish species were examined for visible external anomalies. For gamefish, the anomalies present on each individual fish were recorded. For nongame fish, the number of fish of each species with each anomaly type was recorded. No differentiation was made between a fish with only one anomaly and one fish that had several (e.g., a fish that had both black spot and anchor worm was counted once in each of those categories). The numbers reported here assume that the maximum number of anomalies occurred (per fish). Therefore, the numbers may slightly underestimate the number of nongame fish with anomalies. Values were first summarized as the percentage of fish exhibiting anomalies (Table 4-5). Overall occurrence of anomalies was lower among gamefish (2%)

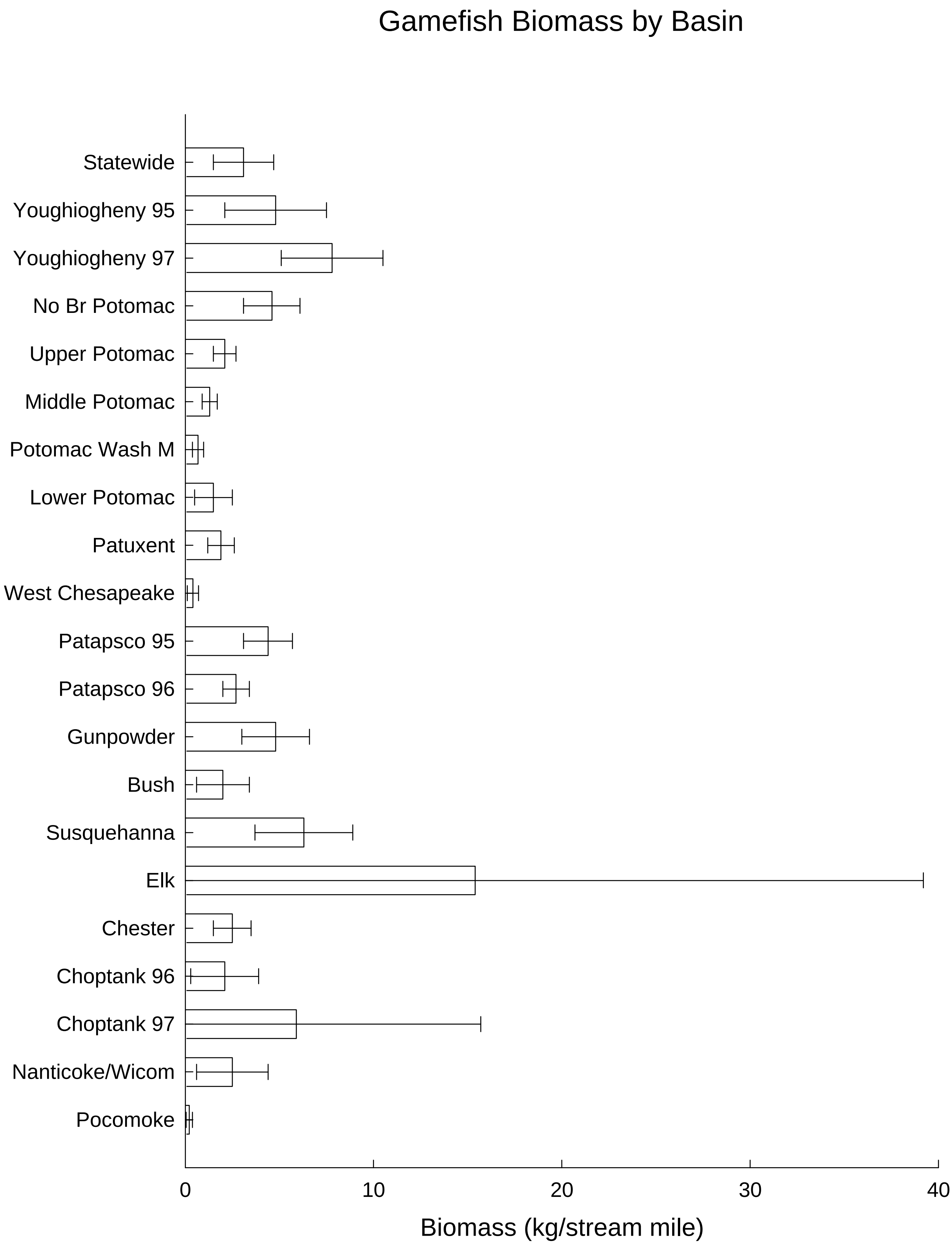


Figure 4-11. Gamefish biomass (kg per stream mile), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error. Biomass estimates are adjusted for capture efficiency.

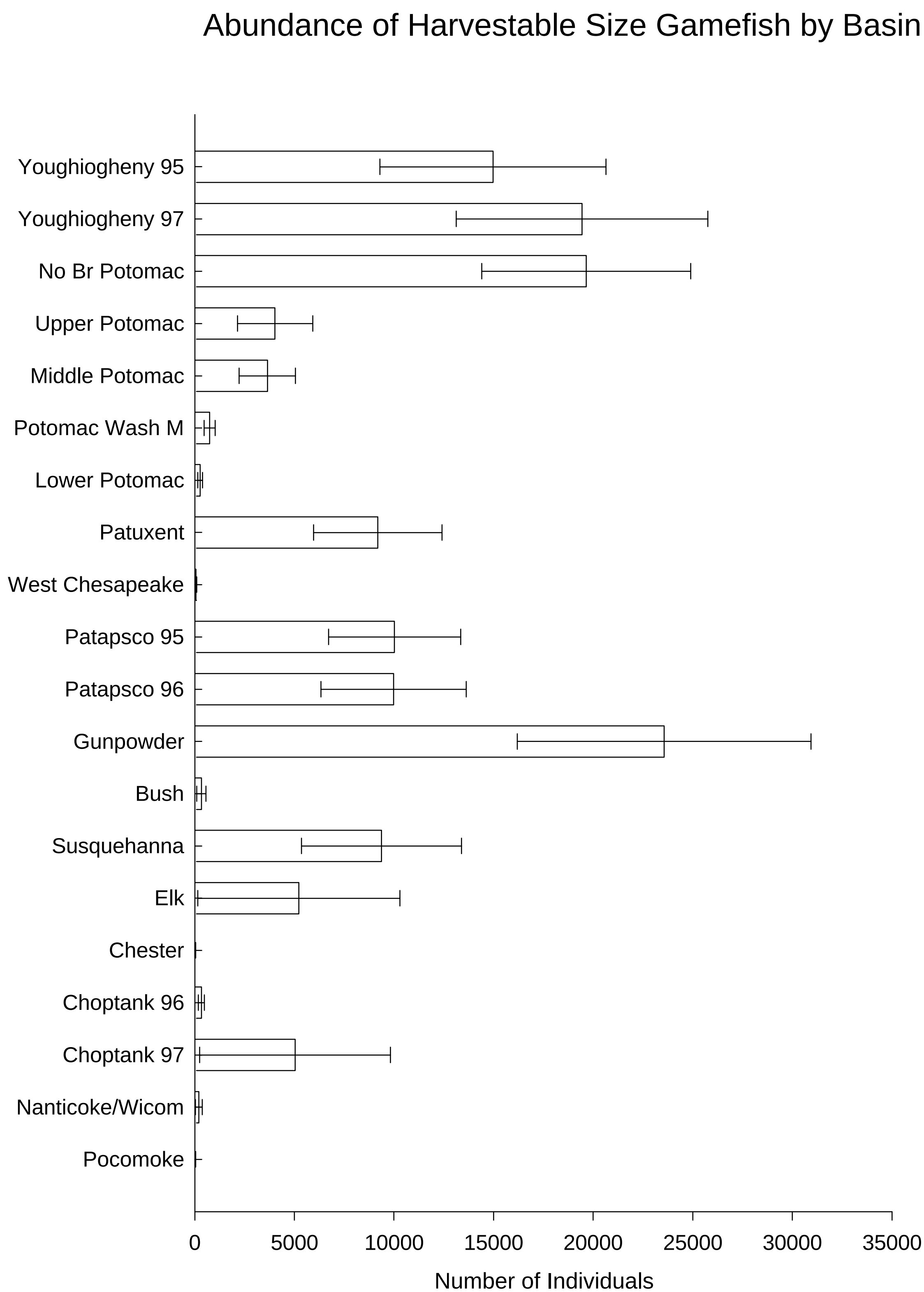


Figure 4-12. Estimates of the total abundance of harvestable size gamefish (number of individuals), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error. Abundance estimates are adjusted for capture efficiency.

Table 4-5. Occurrence of anomalies (percent of fish with anomalies) among game and nongame fish for basins sampled in the 1995-1997 MBSS. These estimates include all recorded anomaly types.

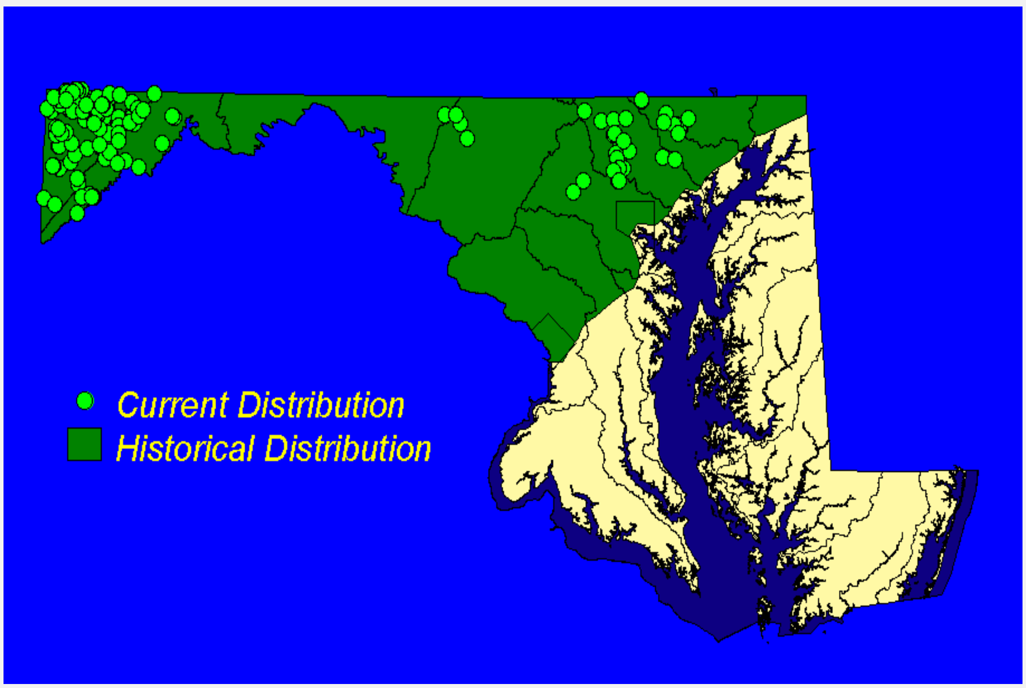
	Percent of Gamefish with Anomalies	Standard Error	Percent of Nongame Fish with Anomalies	Standard Error
Basin				
Youghiogheny 1995	0.9	0.6	5.9	0.7
Youghiogheny 1997	0.3	0.2	3.3	0.6
North Branch Potomac	4.3	2.1	11.8	1.5
Upper Potomac	11.3	3.3	9.8	0.9
Middle Potomac	6.0	1.5	9.1	0.8
Potomac Washington Metro	6.0	0.9	4.6	0.9
Lower Potomac	1.6	1.6	1.9	0.3
Patuxent	0.9	0.6	2.8	0.4
West Chesapeake	0.8	0.02	1.4	0.8
Patapsco 1995	0.9	0.5	5.1	0.7
Patapsco 1996	2.2	1.1	8.2	1.1
Gunpowder	0.1	0.1	5.3	0.5
Bush	8.1	3.2	9.4	2.6
Susquehanna	1.1	0.6	2.7	0.4
Elk	37.1	17.8	6.7	0.6
Chester	2.2	1.6	3.2	0.9
Choptank 1996	0.6	0.7	1.3	0.2
Choptank 1997	0.5	0.4	0.7	0.2
Nanticoke/Wicomico	0	0	0.9	0.3
Pocomoke	4.5	3.2	1.1	0.3
Stream Order				
1	1.7	2.4	4.1	0.4
2	1.1	1.0	6.4	1.1
3	4.4	2.1	6.9	1.2
Statewide	2.1	1.5	5.3	0

* Variance statistically undefined

Brook Trout - Past, Present, and Future

Results from the Survey indicate that between 200,000 and 400,000 brook trout now live in Maryland. This is a small fraction of the number thought to exist before European colonization. Based on the calculations described below, more than 2.9 million brook trout once existed in Maryland streams.

To estimate the size of the pre-European population, brook trout densities at MBSS sites most comparable to historical conditions (559 brook trout per stream mile) were extrapolated to the geographic area that likely approximates the historical distribution of brook trout (all of Maryland west of the Coastal Plain or 4,841 stream miles). The following four assumptions were used in this analysis:



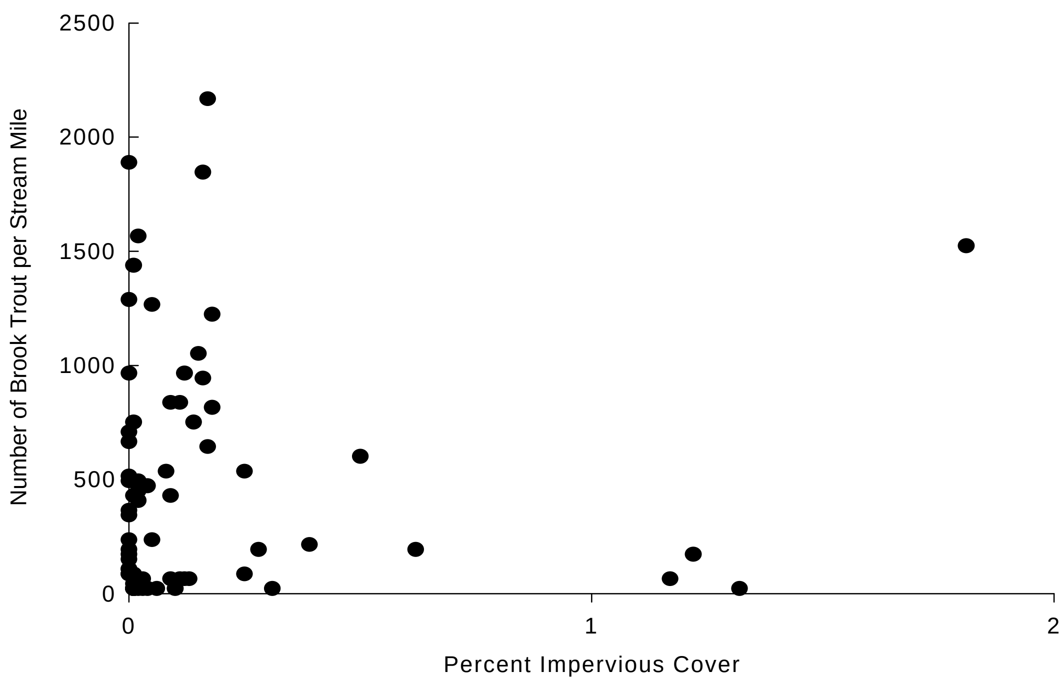
- Assumption 1 - Prior to European settlement, brook trout occurred only in first- through third-order streams. *It is possible that brook trout historically inhabited fourth-order streams that were more shaded than they are today. Therefore, the estimate of historical abundance may be conservative.*

- Assumption 2 - Small streams not included in the MBSS sample frame did not contain historical populations of brook trout. *It is almost certain that brook trout historically inhabited small streams not captured by the 1:250,000 scale reach file employed for the Survey. Therefore, the estimate of historical abundance may be conservative.*

- Assumption 3 - All streams west of the Coastal Plain contained populations of brook trout. *Because it is unlikely that brook trout were found in every watershed within these physiographic regions, the estimate of historical abundance may be an overestimate of the historical population size. On the other hand, brook trout may have historically extended into the Coastal Plain, especially near the transition zone with the Piedmont. Jabez Branch, a tributary to the Severn River, harbored what may have been a relic population of brook trout until they were extirpated in 1989. If at least some Coastal Plain streams had habitat suitable for brook trout, it would lessen the overestimate under this assumption.*

- Assumption 4 - The current mean brook trout density in non-degraded Maryland streams corresponds to the densities existing during the pre-European period. *This value is based on densities observed at sites rated as "good" or "not bad" during the1995-1997 MBSS Survey (see Roth et al. 1997, Appendix C for a definition of 'good' and 'not bad'). Since embeddedness in brook trout streams is almost certainly higher today (and productivity of forage lower) compared to pre-European conditions, the brook trout densities today may be considerably lower than the historical densities. Therefore, the estimate of historical abundance may be conservative.*

Even though considerable uncertainty is associated with the above assumptions, it is clear that the abundance of brook trout has declined dramatically from its historical levels. Although the reasons for the decrease in brook trout are many, one of the most important may be increases in water temperature. As trees were cleared for agriculture and housing, previously forested streams were exposed to direct sunlight as well as to heated water running off impervious surfaces like roads and rooftops. Today, fewer and fewer streams have temperature regimes suitable for brook trout, particularly in the eastern half of the State. The graph below dramatically illustrates that the majority of brook trout exist in watersheds with less than 0.5% impervious surface, and that none exist in watersheds with greater than 2% impervious surface. Other major threats to the continued existence of brook trout in Maryland include (1) silt from new construction and agriculture, (2) competition from non-native brown trout, (3) habitat loss from logging, (4) loss of forests along streams, (5) acid rain, and (6) global warming.



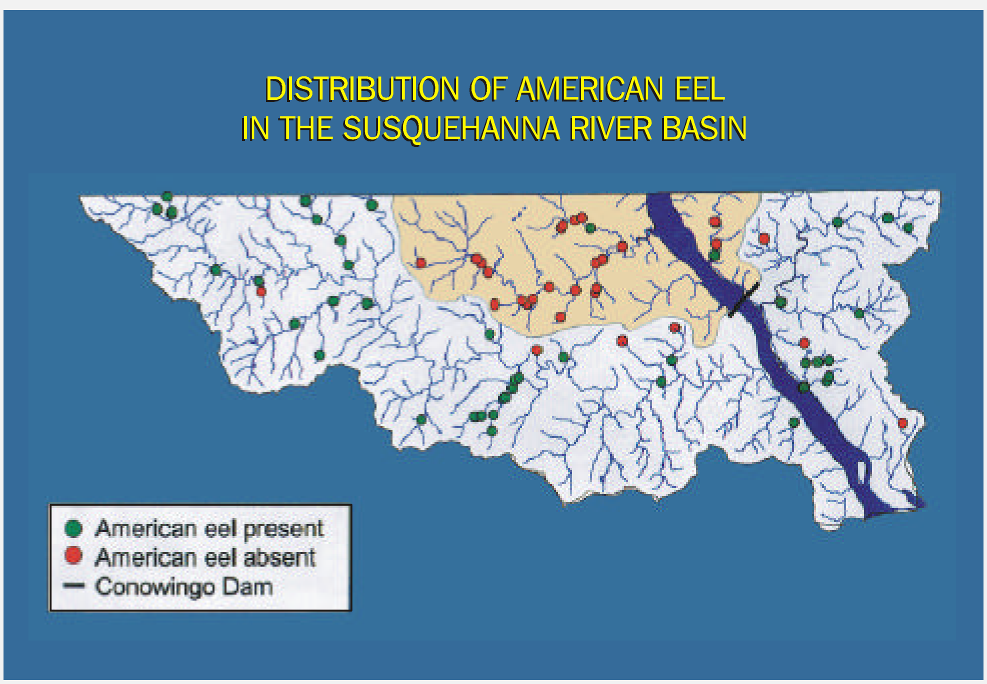
Relationship between watershed imperviousness and brook trout density at MBSS sites sampled during 1995-1997.

American Eel - Past, Present, and Future

The American eel has a life history unique among Maryland fish species. In contrast to anadromous fish (such as American shad) that spawn in Maryland's freshwater rivers and grow to maturity in the ocean, the catadromous eel spawns in the tropical Atlantic ocean and grows to maturity in estuarine and freshwater habitats. Juvenile eels (or elvers) must migrate upstream through estuaries, rivers, and streams to reach habitats that will support them (for 20 years or more) before reaching sexual maturity and migrating to their spawning area in the Sargasso Sea. European colonization of Maryland was accompanied by the construction of numerous small dams to supply water power for mills. Later, dams on larger streams and rivers were added for transportation, water supply, flood control, and hydroelectric projects. Today, the more than 1,000 man-made barriers to migratory fish in Maryland (Leasner, DNR, pers. comm.) have reduced access of American eel and other fish to their historical habitats.

It is likely that the American eel was abundant in virtually all the estuaries, rivers, streams, and lakes of Maryland and other coastal states prior to the colonization of North America. Since that time, the fate of eel stocks in Maryland streams has been similar to the fate of the brook trout. While brook trout populations have declined or disappeared as a result of sometimes subtle changes in the water and habitat quality, the more robust and resilient eel has declined as a result of the cumulative effect of pollution, heavy exploitation, and extensive and major changes to the habitats through which it migrates and in which it grows to maturity.

The most dramatic evidence for the impact of major dams on eel abundance can be found in the Susquehanna River basin. Prior to completion of four mainstem dams on the lower Susquehanna (the last, Conowingo Dam, was built in 1928), eels were common throughout the Susquehanna basin and were popular with anglers in Pennsylvania lakes (PCF 1897). Annual harvests of eels in the Susquehanna were nearly 1 million pounds at that time (Foster 1995). For many decades, there have been no recreational or commercial harvests of this species in Pennsylvania. MBSS data suggest that the mainstem dams have been a major factor in this decline by blocking the upstream migration of juvenile eels.



The MBSS sampled 37 sites within the Maryland portion of the Susquehanna River basin. Of these sites, 11 were on Susquehanna tributaries that emptied into Conowingo Pond upstream of the dam. The remaining 26 sites were located on tributaries, such as Deer Creek, that empty into the river below the dam. At the 11 above-dam sites, only a single eel was taken during sampling. In contrast, eels were captured at 25 of the 26 sites sampled on the below-dam tributaries; the average number of eels taken per station was 37, with a high of 150 at one station on Basin Run. While no fisheries survey data are available for Pennsylvania and New York rivers and streams in the Susquehanna watershed, it is reasonable to conclude from the MBSS and anecdotal fisheries data that the watershed is essentially devoid of eels at the present time.

MBSS data can be used to estimate the probable loss in eel production attributed to mainstem barriers in the Susquehanna basin. Mean eel density was calculated based on the densities observed during the 1995-1997 MBSS, with first-, second-, and third-order stream sites weighted by their relative abundance in the Maryland portion of the Susquehanna basin. If we assume that the mean density of American eel in the Susquehanna basin below Conowingo Dam (approximately 500 per stream mile) is representative of the potential mean density of eels in all streams in the basin (26,064 miles), we estimate that the decline in abundance could be as great as 13 million eels. This estimate assumes no production of eels in any of the lakes and ponds in the watershed, and also ignores the fact that the density of eels in fourth-order and larger streams common in the watershed is greater than the density in third-order and smaller streams, as was found in MBSS supplemental survey sampling in some larger streams. Thus, it is likely that this is a conservative estimate of eel losses.

A recent report documents an apparent continent-wide decline in American eel abundance since the early 1980s (Richkus and Whalen 1999). Such a decline is of great significance, since all eels found in North and South America are produced by a single spawning stock. Contributing factors to this decline have been hypothesized to include changes in ocean currents, pollution, excessive exploitation, hydroelectric facility impacts, migration barriers, and other types of habitat alteration. While no specific causative factor has been identified to date, any measures that would enhance the production and survival of eels throughout their range would contribute to stemming or reversing the apparent decline. MBSS findings suggest that providing for the successful upstream passage of juvenile eels at mainstem dams on the Susquehanna River is such a measure.

than nongame fish (5%) and tended to increase with stream size. Using the less conservative estimate that each fish had only one type of anomaly, 12% of nongame fish would have anomalies. Values in Table 4-5 represent all anomalies recorded, including hooking injuries, cuts, ich, and the presence of visible parasites such as black spot and leeches. Statewide, the occurrence of each anomaly type in nongame fish was low, with almost every type found in less than 0.1% of fish (Table 4-6). Only black spot (8.2%) and red spot (2.5%) were found in greater than 1% of fish statewide. The same results were observed in the individual basins. While more than five anomaly types occurred in every basin sampled, only black spot, eye cloudiness, and red spot occurred in more than 1% of nongame fish in any of the basins sampled. Among gamefish, these numbers were even lower (Table 4-7). Statewide, 18 of the 28 anomalies examined for were found, with only black spot occurring in more than 1% of gamefish. For each individual basin, the occurrence of gamefish with anomalies was also low, with only nine basins containing greater than 1.0% of fish with anomalies. The Nanticoke/Wicomico basin did not contain any gamefish with anomalies, while the greatest percentage of gamefish with anomalies occurred in the Elk basin. This result may be a result of small sample size, as only 18 sites were sampled in the Elk and only nine gamefish were caught there.

Particularly for nongame species, the above values to a large degree reflect the frequent occurrence of blackspot, a trematode parasite that is not especially indicative of impaired fish health. Because blackspot is fairly common, the incidence of a subset of anomalies, excluding blackspot and other parasites, injuries, and ich, was estimated. This subset included only pathological anomalies, which fell into three groups: ocular, skeletal, and skin anomalies (Table 4-8). The occurrence of these pathological anomalies is a potential indication of anthropogenic stress to fish communities.

Table 4-6. Percent occurrence of anomaly types in nongame fish for the 1995-1997 MBSS. Shading indicates anomaly occurs in greater than 1.0% of fish.

	Statewide	Youghiogheny 1995	Youghiogheny 1997	North Branch Potomac	Upper Potomac	Middle Potomac	Potomac Washington Metro	Lower Potomac	Patuxent	West Chesapeake	Patapsco 1995	Patapsco 1996	Gunpowder	Bush	Susquehanna	Elk	Chester	Choptank 1996	Choptank 1997	Nanticoke/Wicomico	Pocomoke
Swelling of the Anus	<0.1				<0.1			<0.1			<0.1		<0.1								
Anchor Worm	<0.1	0.5		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1						<0.1	<0.1		<0.1	<0.1		
Black Spot	8.2	10.0	4.5	15.0	15.4	15.4	4.6	0.6	2.4	0.2	8.8	14.0	8.8	19.8	4.6	16.6	3.6	0.4	<0.1	<0.1	<0.1
Body Shape	<0.1	<0.1				<0.1		<0.1		<0.1	<0.1	<0.1			<0.1		<0.1				
Cataract	<0.1					<0.1	<0.1		<0.1		<0.1			<0.1	<0.1					<0.1	
Cut	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1				<0.1				<0.1		0.3
Discoloration	<0.1	<0.1											<0.1		<0.1			<0.1	<0.1		<0.1
Deformities of the Mandible	<0.1	<0.1			<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2
Deformities of the Vertebrate Column	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1		<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1			<0.1
Eye Cloudiness	<0.1					<0.1		<0.1		1.0	<0.1	<0.1	<0.1		<0.1		<0.1	<0.1	0.7	0.3	<0.1
Eye Hemmorrhage	<0.1				<0.1			<0.1			<0.1				<0.1				<0.1		
Visible External Parasites	0.2	0.3		0.3	0.2	<0.1	<0.1	0.7	<0.1	<0.1	0.3	<0.1	<0.1	<0.1	0.2	<0.1	0.2	<0.1	<0.1	0.2	<0.1
Fin Deformed or Missing	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1			<0.1	<0.1		<0.1	<0.1	<0.1	<0.1
Fin Erosion	0.3	0.3	<0.1	<0.1	0.4	0.4	0.2	0.5	0.3	<0.1	0.4	0.4	<0.1		0.2	<0.1	<0.1	0.2	<0.1	<0.1	0.3
Fungus	<0.1	<0.1		<0.1	<0.1	<0.1		<0.1		<0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1		
Growths/Cysts	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	0.3	<0.1	0.9		<0.1	<0.1
Hooking Injury	<0.1	<0.1			<0.1																
Hemorrhaging	0.2	0.2		0.2	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	0.7	0.4	<0.1	<0.1	0.7	0.2	<0.1	<0.1	0.4
Ich	<0.1											<0.1									
Leeches	<0.1	<0.1		0.3	0.6	0.2	<0.1	0.2	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1
Eye Missing	<0.1	<0.1				<0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1		<0.1
Depression Into the Orbits	<0.1				<0.1				<0.1		<0.1				<0.1						
Other	<0.1	<0.1				<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1		<0.1		<0.1	<0.1	<0.1
Exopthalmia	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1		<0.1		<0.1	<0.1	<0.1
Red Spot	2.5	3.3	1.1	8.3	6.3	4.4	2.9	1.2	2.0		2.0	2.6	4.1	1.2	1.8	0.7					
Raised Scales	<0.1	<0.1			<0.1						<0.1		<0.1								
Scale Deformities	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1			<0.1						
Ulcerations/Lesions	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	0.3	<0.1		<0.1	<0.1	<0.1	<0.1	0.3	<0.1	0.2	0.4	0.3	0.2	0.2

Table 4-7. Percent occurrence of anomaly types in gamefish for the 1995-1997 MBSS. Shading indicates anomaly occurs in greater than 1.0% of fish.

	Statewide	Youghiogheny 1995	Youghiogheny 1997	North Branch Potomac	Upper Potomac	Middle Potomac	Potomac Washington	Lower Potomac	Patuxent	West Chesapeake	Patapsco 1995	Patapsco 1996	Gunpowder	Bush	Susquehanna	Elk	Chester	Choptank 1996	Choptank 1997	Nanticoke/Wicomico	Pocomoke
Swelling of the Anus																					
Anchor Worm	<0.1					0.6	1.4														
Black Spot	1.0			<0.1	2.8	3.3	0.8		<0.1		0.3	1.2	8.1	0.2	30.1	0.9	0.6				
Body Shape																					
Cataract	<0.1	0.3										0.3									
Cut	0.2	0.3	<0.1	0.3	0.9	0.5	2.3								<0.1	3.5					
Discoloration																					
Deformities of the Mandible	<0.1			<0.1	0.5																
Deformities of the Vertebrate Column	<0.1	<0.1						0.3													
Eye Cloudiness	<0.1				0.5						<0.1	0.3									
Eye Hemmorrhage	<0.1														0.5						
Visible External Parasites	<0.1			<0.1	0.9	0.8		0.8	0.2		0.2										
Fin Deformed or Missing	0.2		0.2	1.9						0.3											
Fin Erosion	0.2	0.2		0.8	0.8	0.6			0.3	0.5	0.3	0.3			<0.1		1.4				2.2
Fungus	<0.1						0.8												0.5		
Growths/Cysts	<0.1															3.5					
Hooking Injury	<0.1	<0.1		0.5	2.2		0.8														
Hemorrhaging	<0.1							0.3													
Ich																					
Leeches	<0.1			0.3	2.8	0.3															
Eye Missing																					
Depression Into the Orbits																					
Other	<0.1														<0.1						
Exopthalmia																					
Red Spot																					
Raised Scales																					
Scale Deformities																					
Ulcerations/Lesions	<0.1							0.3				<0.1	<0.1								2.2

Table 4-8.	Three general categories of pathological anomalies observed in fish, with specific types of anomalies that fall under each
	Ocular Anomalies
	Eye Cloudiness Eye Hemorrhage Exopthalmia (pop eye) Depression into the Orbits Eye Missing Cataract
	Skin Anomalies
	Discoloration Hemorrhaging Fin Cloudiness Raised Scales Growths/Cysts Ulcerations/Lesions Fin Erosion Swelling of the Anus Scale Deformities Fin Deformed or Missing
	Skeletal Deformities
	Deformities of the Vertebral Column Deformities of the Mandible Body Shape

Overall, pathological anomalies were observed infrequently in both gamefish (0.8%) and nongame fish (0.5%). A variety of skin anomalies were found on about 0.7% of the individual gamefish, while ocular and skeletal anomalies were observed on less than 0.1% of the gamefish (Figure 4-13). Pathological anomalies were slightly more common in gamefish of third-order streams (2.0%), perhaps indicating (1) a greater influence of point source discharges in larger streams or (2) the cumulative effects from upstream sources. Larger, older fish usually found in third-order streams may also have more anomalies than juveniles collected in smaller headwater streams. Pathological anomalies on gamefish were most common in the Elk basin (Table 4-9, Figure 4-14), although this estimate may again be attributed to small sample size. Among nongame fish, pathological anomalies occurred infrequently (Table 4-10, Figure 4-15). Statewide, less than 0.5% of nongame fish had pathological anomalies.

Another way to summarize the occurrence of anomalies in fish is to estimate the percentage of stream miles having fish with certain anomaly types. For all fish, pathological anomalies occurred in 44% of stream miles. The Choptank basin had the greatest percentage of stream miles (83%) with fish exhibiting pathological anomalies. Skin anomalies made up the greatest percentage of these anomalies, occurring at 40% of stream miles statewide (Figure 4-16).

For gamefish, the overall occurrence of pathological anomalies was not widespread. Based on 1995-97 MBSS sampling, only about 2% of stream miles had gamefish with any type of pathological anomaly (Table 4-11, Figure 4-17). Most of these anomalies were skin anomalies, with the highest percentage occurring in the Elk basin (11%). Less than 1% of stream miles had gamefish with ocular or skeletal anomalies. Estimates are based on data from all sites sampled during the summer index period.

Among nongame fish, pathological abnormalites were observed more frequently (Table 4-12, Figure 4-18). An estimated 40% of stream miles had nongame fish with skin anomalies. Skin anomalies were observed in an estimated 73% of third-order streams, 55% of second-order streams, and 31% of first-order streams. The greater extent of anomalies in second- and third-order streams could reflect

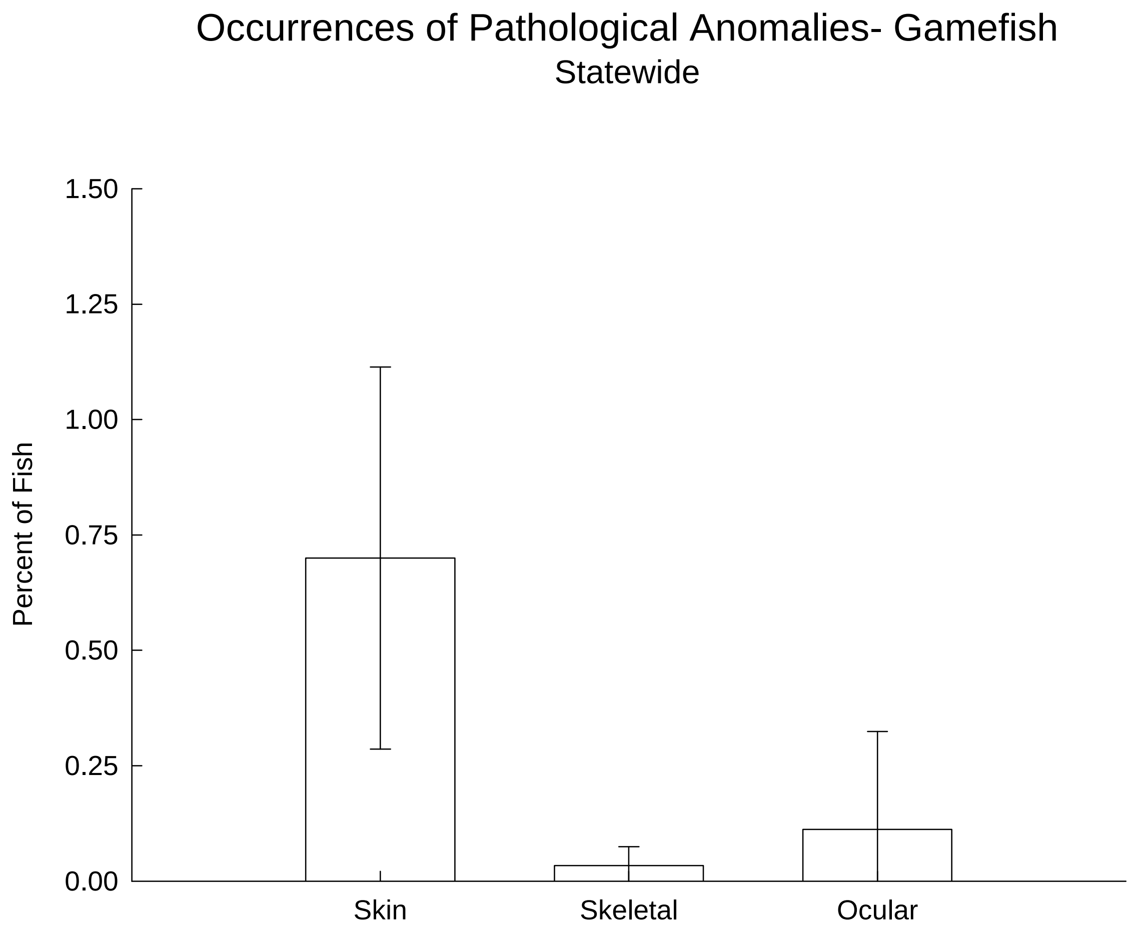


Figure 4-13. Percentage of fish with each type of pathological anomaly (skin, skeletal, or ocular), statewide for the 1995-1997 MBSS. Error bars signify ±1 standard error.

more degraded water quality and the presence of larger, older individuals in larger streams. Skin anomalies in nongame fish were most prevalent in the Choptank basin (1996 sampling), where occurrence was estimated at 80% of stream miles. In contrast, the Youghiogheny basin (1997 sampling) had only 5% of stream miles with nongame fish exhibiting skin anomalies. Ocular anomalies in nongame fish occurred less often, in about 9% of stream miles overall. Again, estimates were highest for third-order (19%) and second-order (14%) stream miles. Ocular anomalies were most prevalent in nongame fish in the Susquehanna basin (28% of stream miles). Skeletal deformities in nongame fish were estimated to occur in about 7% of stream miles statewide, and were slightly higher in second and third-order streams. The Pocomoke basin had the highest incidence of skeletal anomalies in nongame fish (29% of stream miles).

Some programs have successfully employed the prevalence of anomalies as one component of a fish Index of Biotic Integrity (IBI) (e.g., Ohio EPA 1987). However, in developing a fish IBI for Maryland, the incidence of anomalies (total or pathological) was ineffective in detecting differences in site condition and was therefore not included in the fish IBI for Maryland (Roth et al. 1998).

Table 4-9. Occurrence of pathological anomalies among gamefish (percent of fish with pathological anomalies) for basins sampled in the1995-1997 MBSS. Estimates include the anomaly types listed in Table 4-8.

	Percent of gamefish with pathological anomalies	**Standard Error**	**Percent of gamefish with skin anomalies**	**Standard Error**	**Percent of gamefish with skeletal anomalies**	**Standard Error**	**Percent of gamefish with ocular anomalies**	**Standard Error**
Basin								
Youghiogheny 1995	0.52	0.32	0.25	0.18	0.00	0.00	0.27	0.26
Youghiogheny 1997	0.25	0.16	0.25	0.16	0.04	0.05	0.00	0.00
North Branch Potomac	2.90	1.84	2.90	1.84	0.14	0.14	0.00	0.00
Upper Potomac	2.22	1.06	1.30	0.94	0.46	0.47	0.46	0.42
Middle Potomac	1.10	0.56	1.10	0.56	0.00	0.00	0.00	0.00
Potomac Washington Metro	0.77	0.78	0.77	0.78	0.00	0.00	0.00	0.00
Lower Potomac	0.81	0.78	0.54	0.52	0.27	0.26	0.00	0.00
Patuxent	0.25	0.15	0.25	0.15	0.00	0.00	0.00	0.00
West Chesapeake	0.81	0.02	0.81	0.02	0.00	0.00	0.00	0.00
Patapsco 1995	0.40	0.26	0.30	0.20	0.00	0.00	0.10	0.10
Patapsco 1996	0.99	0.47	0.44	0.32	0.00	0.00	0.55	0.35
Gunpowder	0.06	0.07	0.06	0.07	0.00	0.00	0.00	0.00
Bush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Susquehanna	0.67	0.52	0.14	0.11	0.00	0.00	0.53	0.50
Elk	10.49	6.63	10.49	6.63	0.00	0.00	0.00	0.00
Chester	1.39	1.23	1.39	1.23	0.00	0.00	0.00	0.00
Choptank 1996	0.64	0.72	0.64	0.72	0.00	0.00	0.00	0.00
Choptank 1997	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nanticoke/Wicomico	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pocomoke	4.49	3.21	4.49	3.21	0.00	0.00	0.00	0.00
Stream Order								
1	0.58	0.86	0.48	0.77	0.00	0.00	0.10	0.24
2	0.34	0.36	0.23	0.27	0.00	0.00	0.11	0.43
3	2.00	1.22	1.78	1.10	0.15	0.23	0.14	0.23
Statewide	0.83	0.56	0.70	0.41	0.03	0.04	0.11	0.21

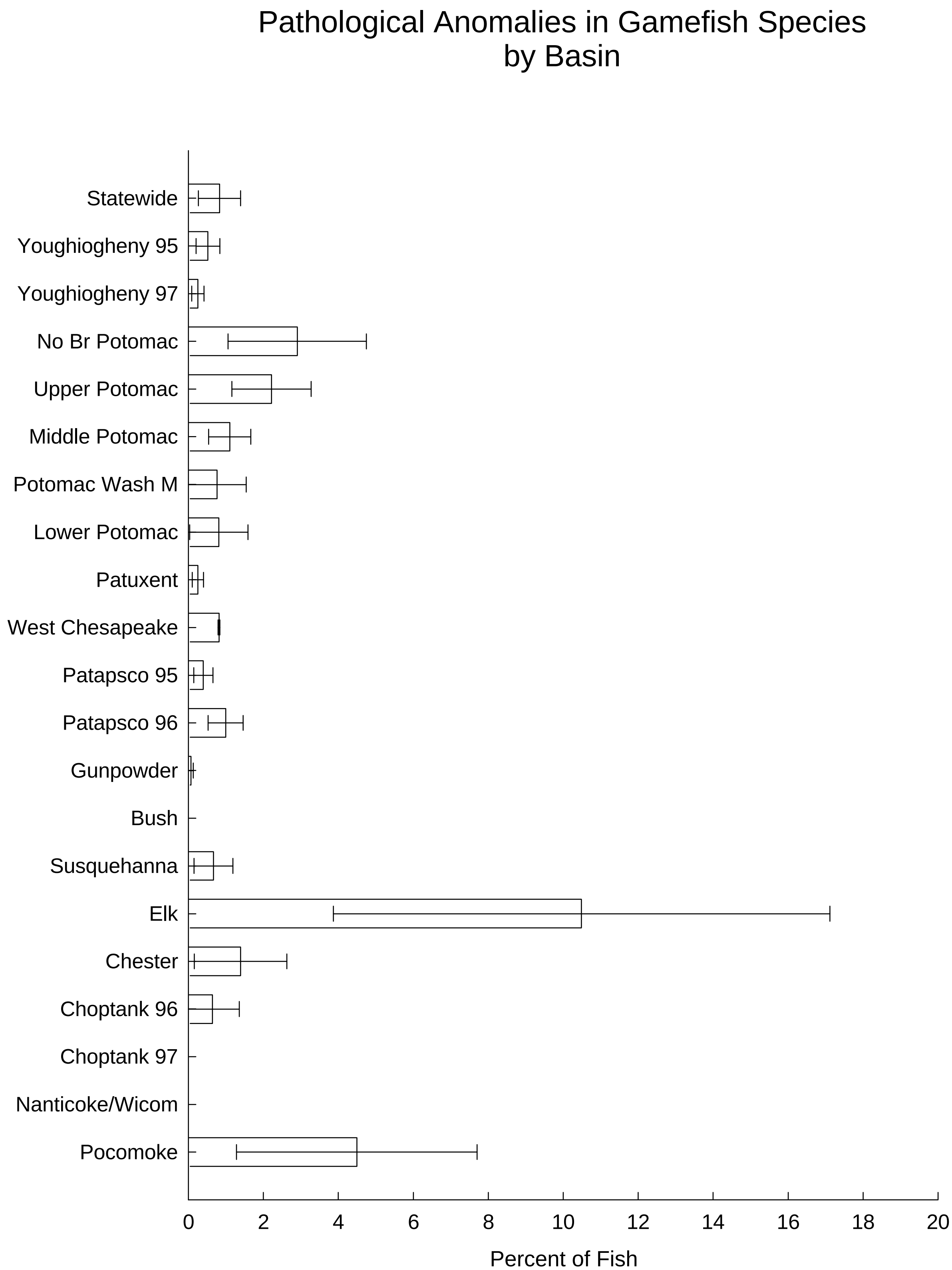


Figure 4-14. Occurrence of pathological anomalies in gamefish (percent of individual gamefish with pathological anomalies), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

Table 4-10. Occurrence of pathological anomalies among nongame fish (percent of nongame fish with pathological anomalies) for basins sampled in the 1995-1997 MBSS. Estimates include the anomaly types listed in Table 4-8.

	Percent of nongame fish with pathological anomalies	**Standard Error**
Basin		
Youghiogheny 1995	0.53	0.12
Youghiogheny 1997	0.10	0.05
North Branch Potomac	0.27	0.08
Upper Potomac	0.38	0.10
Middle Potomac	0.31	0.04
Potomac Washington Metro	0.33	0.09
Lower Potomac	0.61	0.11
Patuxent	0.30	0.07
West Chesapeake	1.14	0.74
Patapsco 1995	0.51	0.10
Patapsco 1996	0.44	0.07
Gunpowder	0.50	0.17
Bush	0.30	0.10
Susquehanna	0.59	0.15
Elk	0.36	0.14
Chester	0.98	0.39
Choptank 1996	1.09	0.24
Choptank 1997	0.58	0.19
Nanticoke/Wicomico	0.79	0.32
Pocomoke	0.84	0.30
Stream Order		
1	0.43	0.22
2	0.47	0.13
3	0.60	0.26
Statewide	0.47	0.10

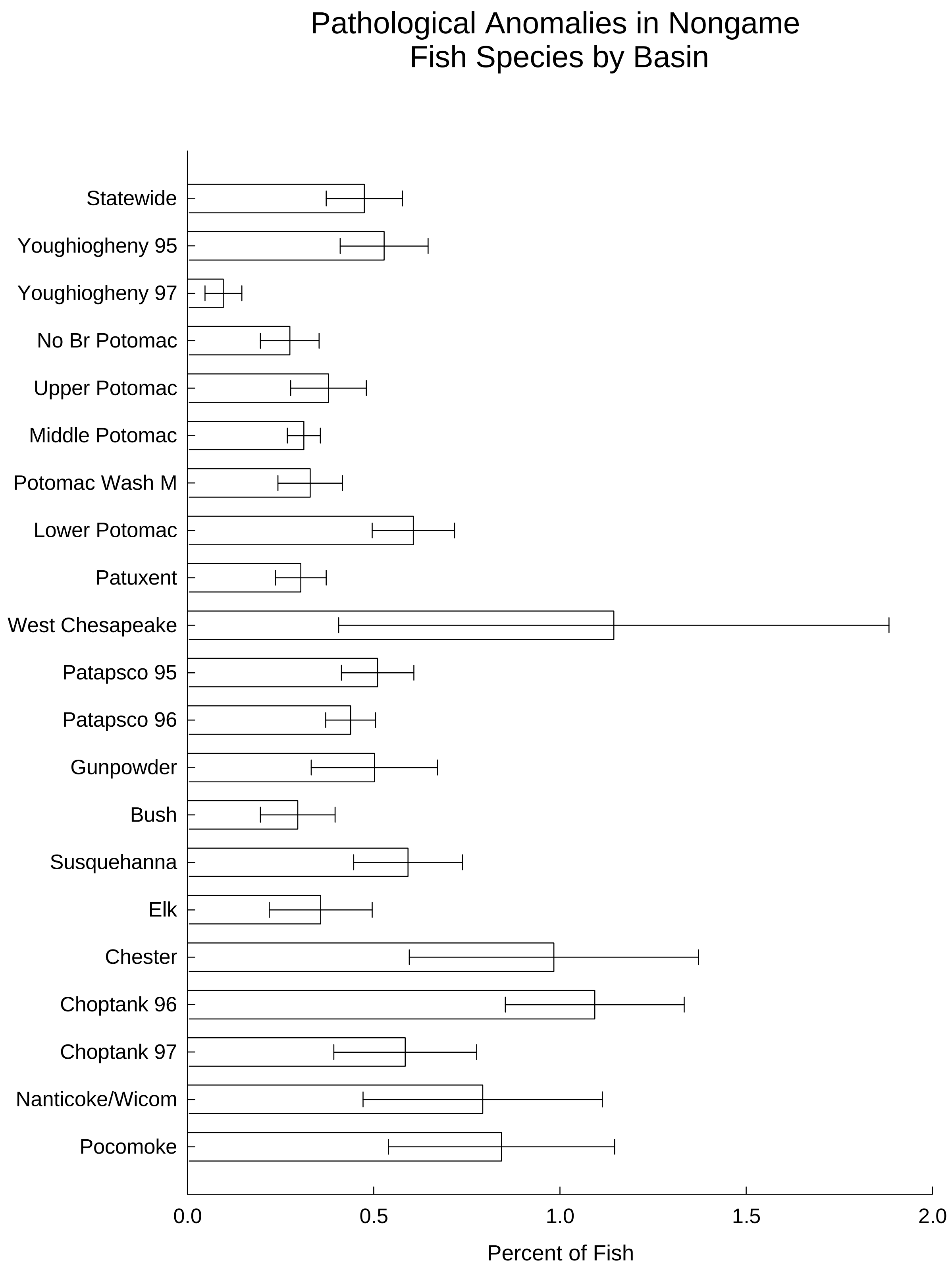


Figure 4-15. Occurrence of pathological anomalies in nongame fish (percent of nongame fish with pathological anomalies), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

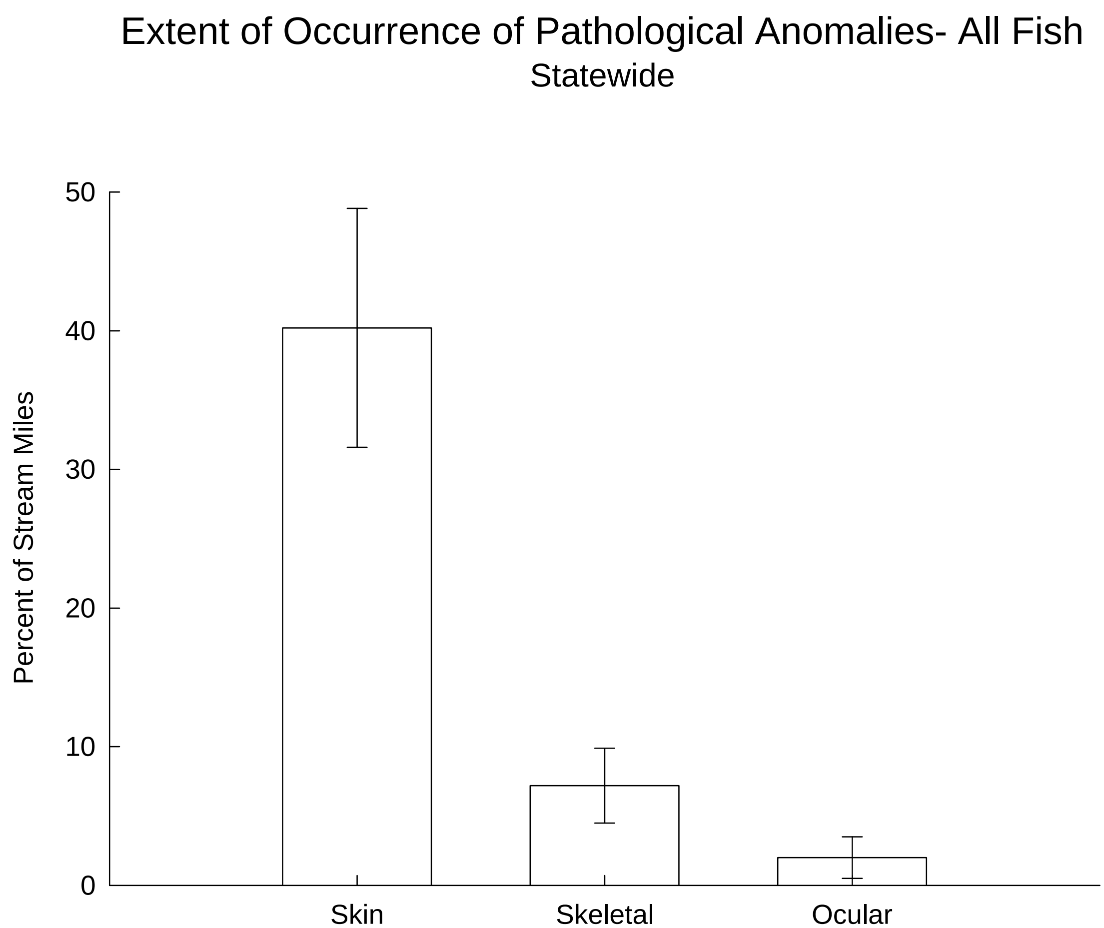


Figure 4-16. Percentage of stream miles containing fish with each type of pathological anomaly (skin, skeletal or ocular), statewide for the 1995-1997 MBSS. Error bars signify ±1 standard error.

Table 4-11. Percentage of stream miles having gamefish with each of three pathological anomaly types, for basins sampled in the 1995-1997 MBSS

	Skin Anomalies		**Ocular Anomalies**		**Skeletal Anomalies**	
	Mean	**Standard Error**	**Mean**	**Standard Error**	**Mean**	**Standard Error**
Basin						
Youghiogheny 1995	1.4	1.0	1.5	1.5	0.0	0.0
Youghiogheny 1997	3.3	1.9	0.0	0.0	0.9	0.9
North Branch Potomac	6.3	1.8	0.0	0.0	0.7	0.7
Upper Potomac	1.4	1.0	0.5	0.5	0.5	0.5
Middle Potomac	1.3	0.6	0.0	0.0	0.0	0.0
Potomac Washington Metro	0.5	0.5	0.0	0.0	0.0	0.0
Lower Potomac	0.6	0.6	0.0	0.0	0.6	0.6
Patuxent	0.9	0.5	0.0	0.0	0.0	0.0
West Chesapeake	1.5	1.5	0.0	0.0	0.0	0.0
Patapsco 1995	1.8	1.3	0.6	0.6	0.0	0.0
Patapsco 1996	0.9	0.6	1.8	1.1	0.0	0.0
Gunpowder	0.7	0.7	0.0	0.0	0.0	0.0
Bush	0.0	0.0	0.0	0.0	0.0	0.0
Susquehanna	1.7	1.2	5.9	5.9	0.0	0.0
Elk	10.5	10.5	0.0	0.0	0.0	0.0
Chester	5.9	5.6	0.0	0.0	0.0	0.0
Choptank 1996	1.1	1.1	0.0	0.0	0.0	0.0
Choptank 1997	0.0	0.0	0.0	0.0	0.0	0.0
Nanticoke/Wicomico	0.0	0.0	0.0	0.0	0.0	0.0
Pocomoke	0.9	0.6	0.0	0.0	0.0	0.0
Stream Order						
1	0.4	0.6	0.3	0.7	0.0	0.0
2	1.1	2.2	0.6	2.1	0.0	0.0
3	11.9	3.9	1.3	2.4	1.6	2.2
Statewide	1.7	0.7	0.5	0.7	0.2	0.2

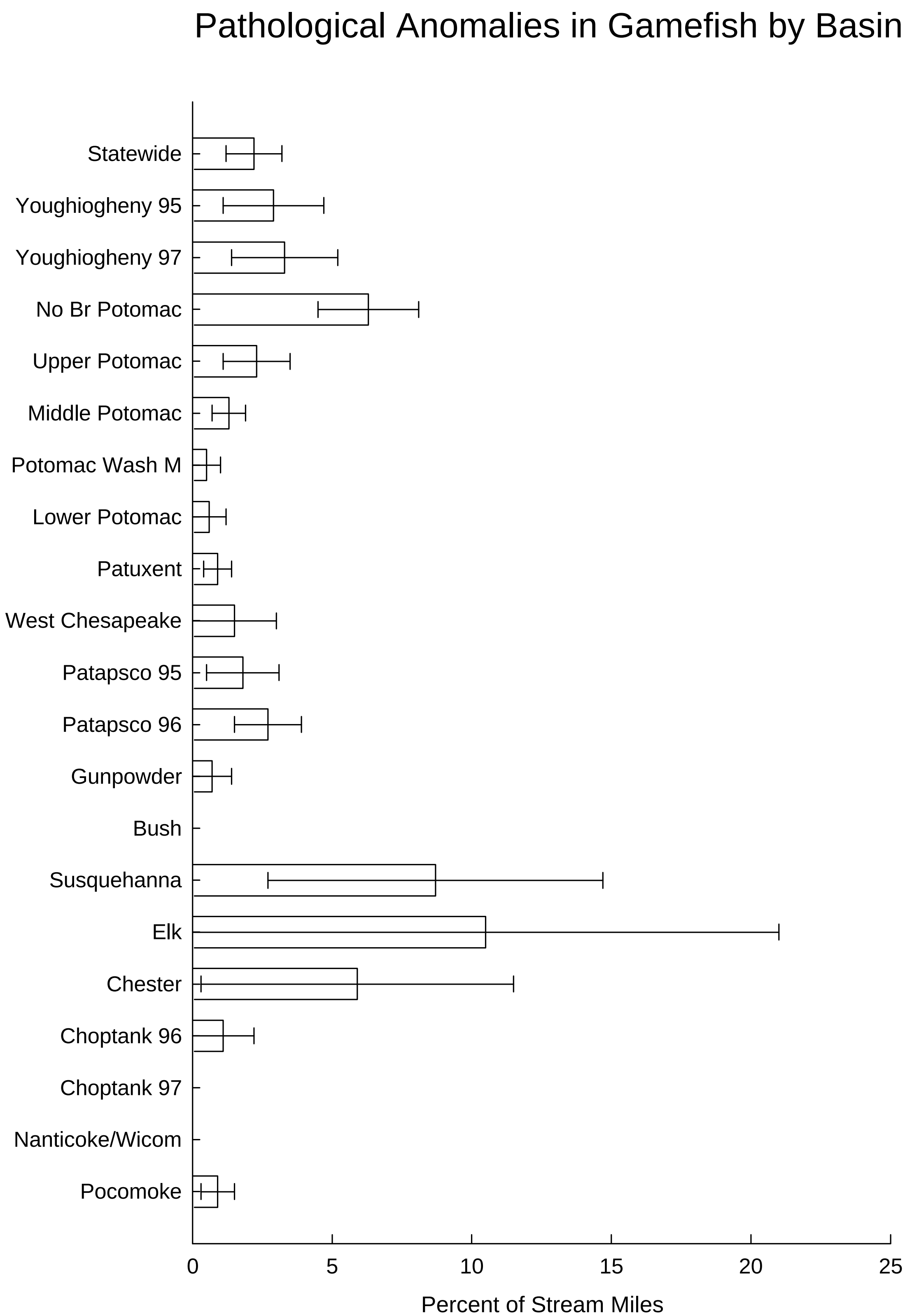


Figure 4-17. Percentage of stream miles with gamefish species having pathological anomalies, statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

Table 4-12. Percentage of stream miles having nongame fish with each of three pathological anomaly types, for basins sampled in the 1995-1997 MBSS

	Skin Anomalies		Ocular Anomalies		Skeletal Anomalies	
	Mean	**Standard Error**	**Mean**	**Standard Error**	**Mean**	**Standard Error**
Basin						
Youghiogheny 1995	48.2	12.4	3.0	2.1	14.9	8.7
Youghiogheny 1997	4.8	2.5	0.0	0.0	1.5	1.5
North Branch Potomac	14.3	3.5	0.0	0.0	2.0	1.5
Upper Potomac	26.4	5.6	3.3	1.7	8.6	4.8
Middle Potomac	39.4	5.8	13.2	3.6	4.8	2.5
Potomac Washington Metro	33.4	7.3	1.3	1.0	0.0	0.0
Lower Potomac	62.6	10.7	22.3	7.7	12.8	5.8
Patuxent	33.8	6.3	5.1	3.2	2.5	2.3
West Chesapeake	9.9	7.9	10.9	8.0	3.6	2.3
Patapsco 1995	56.9	8.4	14.3	3.2	9.9	4.2
Patapsco 1996	46.3	8.2	8.1	3.8	9.5	3.8
Gunpowder	45.1	8.9	10.1	5.7	10.9	5.8
Bush	64.4	16.8	8.1	3.8	2.2	2.2
Susquehanna	62.8	12.1	27.7	10.0	9.1	6.3
Elk	53.1	17.3	2.4	5.4	7.2	4.3
Chester	51.5	12.9	9.0	3.7	9.6	6.1
Choptank 1996	79.5	19.9	2.2	1.5	14.0	11.2
Choptank 1997	20.2	11.2	25.1	11.4	0.8	0.8
Nanticoke/Wicomico	27.7	13.8	19.4	11.7	8.4	8.4
Pocomoke	28.7	13.5	22.8	13.3	29.2	15.6
Stream Order						
1	30.6	11.1	6.4	3.4	6.3	4.1
2	54.8	8.8	14.3	8	8.7	3.3
3	72.7	16.8	18.6	11.6	9.2	7.3
Statewide	39.7	9.1	9.2	2.7	7.1	2.8

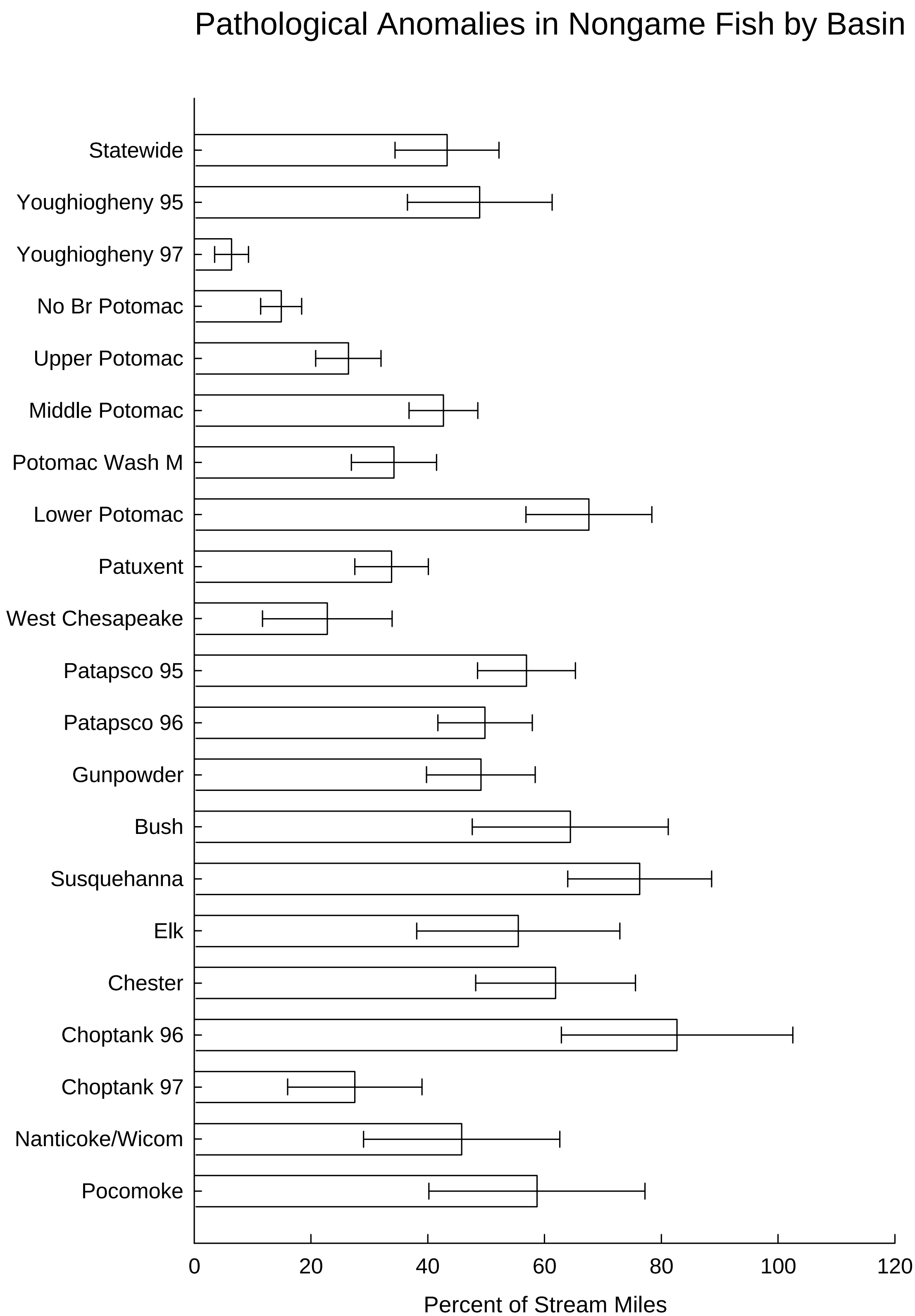


Figure 4-18. Percentage of stream miles with nongame fish species having pathological anomalies, statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

4.2 BENTHIC MACROINVERTEBRATES

Three hundred forty-six (346) genera within 112 families were collected during 1995-1997 MBSS sampling at 955 sites (Appendix C, Table C-3). Among all basins, the Lower Potomac had the highest total number of taxa combined across sites (190), while the Bush and the Elk both had the lowest (83) (Figure 4-19). In general, basins on the Coastal Plain (e.g., Bush, Elk, and Pocomoke) contained the fewest total taxa. The total number of taxa for those basins that traverse the Fall Line (i.e., Gunpowder, Patapsco, Patuxent, and Potomac Washington Metro) had, on average, 15% more taxa than basins not traversing the Fall Line.

Most of the genera sampled during the MBSS were rare. Two hundred eighty-seven (287) genera (83%) occurred at less than 10% of all sites and 161 genera (47%) occurred at less than 1% of all sites. In contrast, only 14 genera (3%) occurred at more than 25% of all sites. The three most common genera were all dipterans—*Parametriocnemus* sp. and *Cricotopus/Orthocladius* sp. (both Diptera: Chironomidae), and *Prosimulium* sp. (Diptera: Simuliidae)—each occurring at more than 50% of all sites. Other common genera and their respective percent occurrences were *Ephemerella* sp. (Ephemeroptera: Ephemerellidae) (46%), *Stenonema* sp. (Ephemeroptera: Heptageniidae) (40%), and *Hydropsyche* sp. (Trichoptera: Hydropsychidae) (42%).

Mean taxa richness per site statewide was 17.3 (Table 4-13; Figure 4-20). Mean taxa richness was highest in the 1995 sampling of the Youghiogheny basin (23.6) and lowest in the Bush basin (10.4). Taxa richness varied little with stream order; the mean richness was 17.0 for all first-order streams, 18.1 for second-order streams, and 17.9 for third-order streams. However, mean taxa richness did increase consistently with watershed size (Figure 4-21). Stream sites with watersheds > 3,000 acres contained, on average, 13% more taxa than sites with watersheds < 300 acres.

4.3 AMPHIBIANS AND REPTILES

Forty-five species of amphibians and reptiles were observed statewide (Appendix C, Table C-4). Because amphibians and reptiles were collected as part of the Survey's stream-based design, they are a sample of those species that reside in streams and their riparian zones. These amphibian and reptiles are a subset of the larger set of herpetofauna of the State that includes many primarily terrestrial species. The 45 species collected by the Survey represent 52% of the amphibians and reptiles known to exist in the State (Harris 1975); a list of species not reported by the Survey is included in Appendix C, Table C-5.

The Lower Potomac basin had the highest amphibian and reptile species richness per stream mile of riparian area (mean of 4.0 species observed per site). Mean species richness in other basins ranged from 1.4 to 3.3 (Table 4-14). As expected from their aquatic habits, amphibian species (frogs, toads, and salamanders) were the most commonly observed groups, with frogs and toads present at an estimated 44% of stream miles and salamanders present at an estimated 40% of stream miles. Reptiles were less frequently observed: turtles were present at an estimated 7% of stream miles, snakes at 5%, and lizards at 0.4%. No strong pattern of total amphibian and reptile species richness was observed among stream orders. Salamanders, however, were significantly more common in smaller streams, occurring in 41% of first-order and 39% of second-order stream miles, but only 27% of third-order stream miles (Figure 4-22). The species richness of salamanders in low-order streams may make them effective indicators of biological integrity in small streams with few or no fish.

Statewide, distinct geographic patterns were evident in both amphibian groups. The presence of each reptile group was lower and widely distributed across the State. More details on the geographic distributions of amphibian and reptile species is provided in Chapter 12. The number of stream miles with salamanders present declines from west to east in Maryland (Figure 4-23). Indeed, no salamanders were recorded in two Eastern Shore basins: the Nanticoke/-Wicomico and Pocomoke. In contrast, frogs were present in a greater percentage of stream miles on the Eastern Shore of Maryland than in other regions of the State (Figure 4-24). These distributions likely reflect the affinity of salamanders for small streams that are abundant in western Maryland and the affinity of frogs for streams associated with wetlands in eastern Maryland.

4.4 MUSSELS

Throughout the United States, native freshwater mussels are imperiled by human impacts. The Nature Conservancy reports that two-thirds of the nation's freshwater mussels are at risk of extinction and that almost 10% may already have gone extinct (TNC 1998). Currently, there are 16 unionid bivalve species reported in Maryland (pers. comm. J. McCann, Maryland Department of Natural Resources, 1998). Of these, 14 are listed as State rare or endangered species and are actively tracked by DNR's Wildlife and Heritage Division.

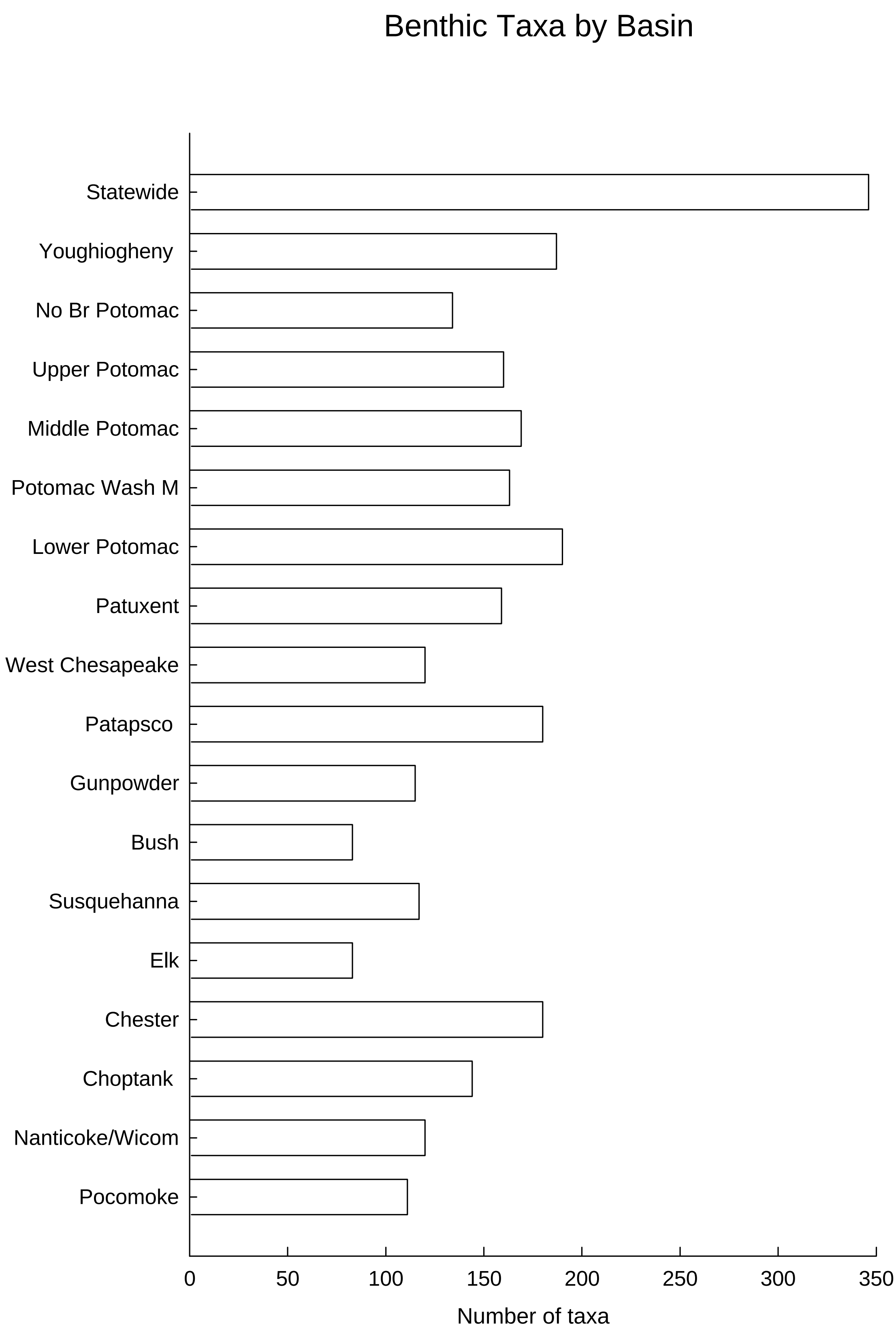


Figure 4-19. Number of benthic taxa, statewide and by basin for the 1995-1997 MBSS

Table 4-13. Benthic taxa richness, by basin and stream order, estimated as mean number of taxa per site, for the 1995-1997 MBSS

	Mean number of benthic taxa per site	Standard Error
Basin		
Youghiogheny 1995	23.6	2.1
Youghiogheny 1997	19.9	2.4
North Branch Potomac	17.4	1.5
Upper Potomac	17.5	1.1
Middle Potomac	14.6	1.2
Potomac Washington Metro	18.7	1.5
Lower Potomac	19.0	2.2
Patuxent	20.0	1.2
West Chesapeake	13.2	2.4
Patapsco 1995	18.3	1.8
Patapsco 1996	12.9	1.3
Gunpowder	18.4	1.6
Bush	10.4	1.9
Susquehanna	19.7	2.0
Elk	16.1	3.4
Chester	18.4	2.7
Choptank 1996	14.2	1.9
Choptank 1997	15.4	2.2
Nanticoke/Wicomico	18.0	4.1
Pocomoke	13.5	1.9
Stream Order		
1	17.0	1.9
2	18.1	2.0
3	17.9	1.2
Statewide	17.3	1.8

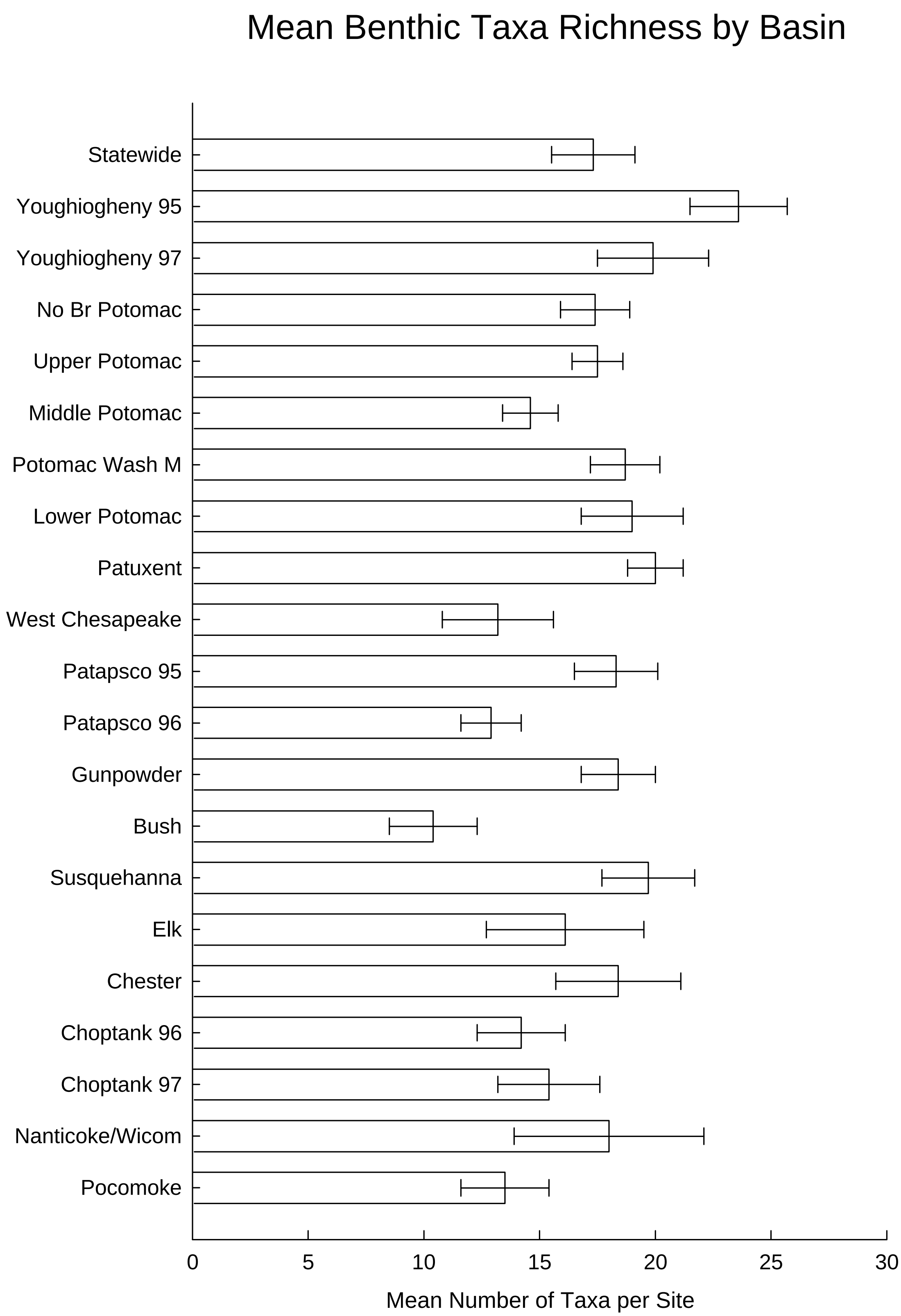


Figure 4-20. Mean benthic taxa richness (mean number of benthic taxa per site), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

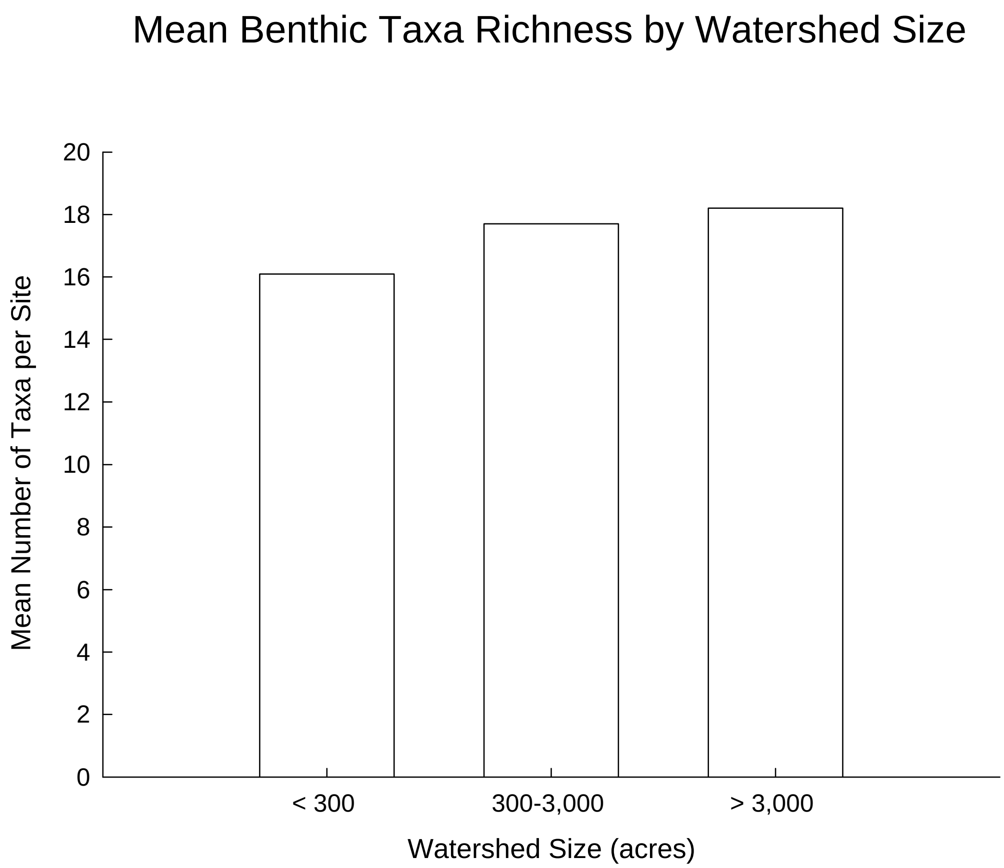


Figure 4-21. Mean benthic taxa richness (mean number of benthic taxa per site), statewide, by watershed size (acres)

Table 4-14. Amphibian and reptile species richness, by basin and stream order, estimated as mean number of species per segment, for the 1995-1997 MBSS

	Mean number of amphibians and reptile species per site	Standard Error
Basin		
Youghiogheny 1995	2.5	0.6
Youghiogheny 1997	1.4	0.3
North Branch Potomac	3.0	0.4
Upper Potomac	2.2	0.3
Middle Potomac	1.8	0.2
Potomac Washington Metro	2.4	0.3
Lower Potomac	4.0	0.5
Patuxent	3.2	0.3
West Chesapeake	2.0	0.4
Patapsco 1995	2.0	0.2
Patapsco 1996	2.1	0.3
Gunpowder	2.2	0.3
Bush	1.7	0.4
Susquehanna	3.2	0.4
Elk	2.1	0.7
Chester	2.6	0.5
Choptank 1996	2.8	0.7
Choptank 1997	3.3	0.8
Nanticoke/Wicomico	1.9	0.5
Pocomoke	2.2	0.6
Stream Order		
1	2.6	0.3
2	2.3	0.2
3	2.1	0.2
Statewide	2.5	0.3

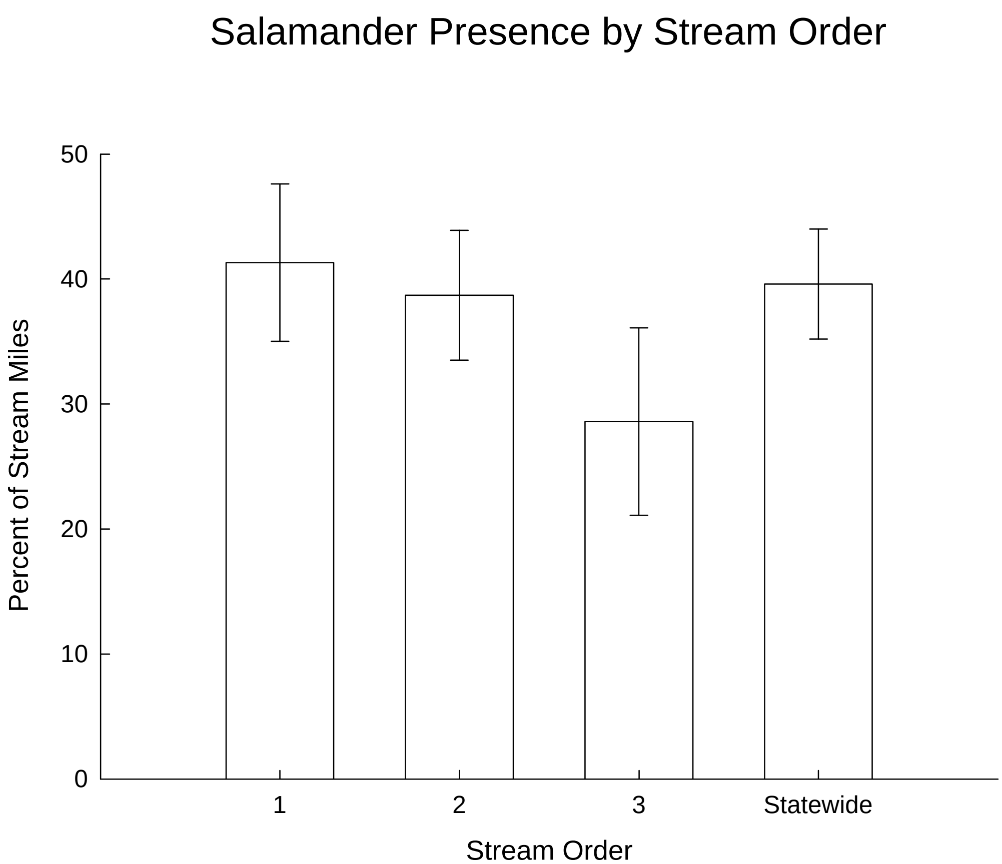


Figure 4-22. Percentage of stream miles with salamanders present, by stream order for the 1995-1997 MBSS. Error bars signify ±1 standard error.

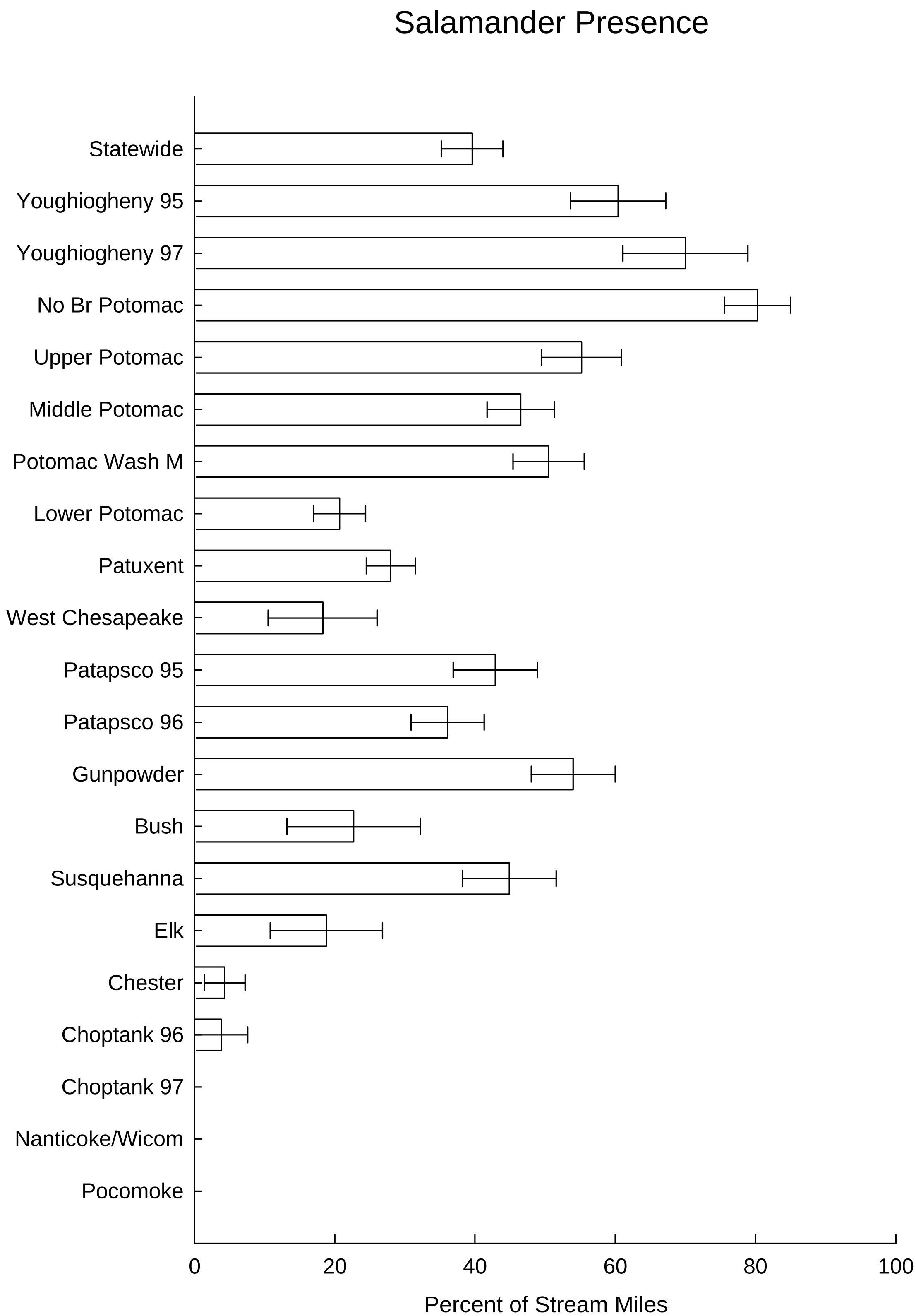


Figure 4-23. Percentage of stream miles with salamanders, statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

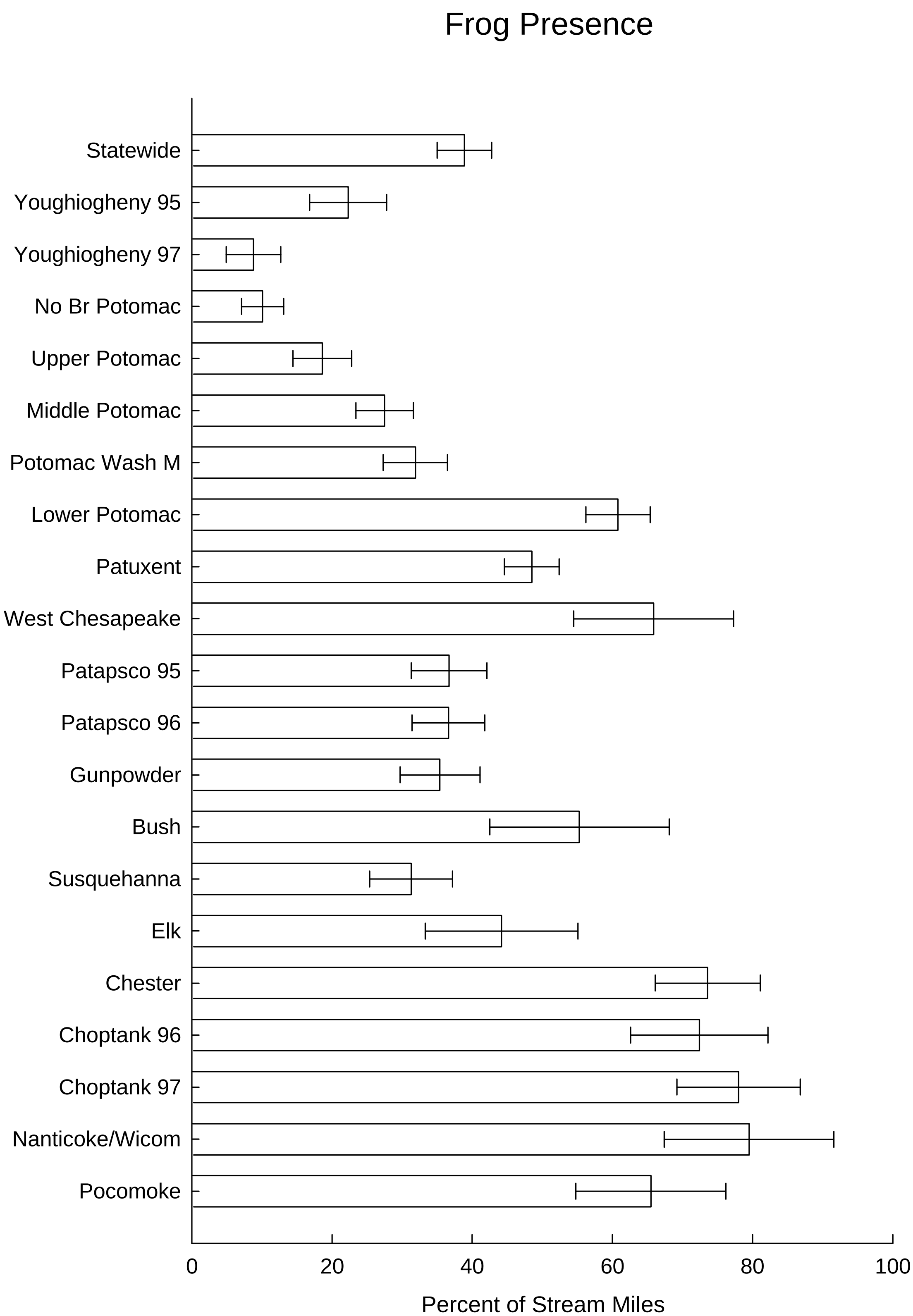


Figure 4-24. Percentage of stream miles with frogs, statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

Eight species of freshwater bivalves were collected in Maryland from 1995-1997 (Appendix C, Table C-6), including seven native unionid species and the introduced Asiatic clam. Five state rare unionid species were observed during the Survey. For further details on rare and introduced species, see Chapter 12.

Sixteen of the basins across the state contained one or more of the species found. The Chester basin had the highest species richness with six native freshwater bivalves collected, whereas no bivalves were collected in the North Branch Potomac basin (Figure 4-25). Overall, freshwater unionid mussels were found at 18% of the 905 core MBSS sites sampled statewide. Strayer (1983) and Watters (1993) have indicated that mussel species diversity in streams often increases as stream order increases. This is consistent with MBSS results for 1995-1997 where unionid mussels were present in 2% of the first-order sites sampled, 9% of the second-order sites, and 19% of the third-order sites.

The two most common freshwater bivalves were the eastern elliptio (occurring at 7.9% of sites) and the introduced Asiatic clam (7.7%). The Asiatic clam, although first introduced to the region in the early 1930's, is now widespread in Maryland, occurring in 13 of the basins sampled (Figure 4-26). Other species of bivalves occurred at less than 1% of all sites sampled. The squawfoot and yellow lance, both listed as rare in Maryland, occurred at only one of 905 sites sampled. Currently, there is concern about the status of the squawfoot due to its rarity in Maryland, as well as the yellow lance which is difficult to identify.

4.5 AQUATIC VEGETATION

Aquatic vegetation communities are an important component of small stream ecosystems, often becoming the primary transducer of energy from sunlight to organic matter in unshaded environments (Lock 1981). Plants also create habitats for invertebrates (Biggs 1996, Newman et al. 1996), slow water velocities (Sand-Jensen and Mebus 1996), trap detritus (Dudley et al. 1986), and provide food and cover for fish (Sevino and Stein 1982). When abundant, aquatic vegetation controls flow conditions, carbon and mineral flux, and the abundance and species composition of invertebrates and fishes (Sand-Jensen and Mebus 1996). Recognizing the importance of aquatic vegetation communities to streams, the Survey recorded the presence and species composition of aquatic vegetation at all sample sites.

During the 1995-1997 MBSS, 24 distinct taxa of aquatic vegetation were identified (Table 4-15; Appendix C, Table C-7). Burreed (*Sparganium* sp.), an emergent, obligate wetland species, was the most abundant species, occurring at 11.3% (102) of the 905 sites sampled. Larger water-starwart (*Callitriche heterophylle*), a submerged aquatic species, occurred at 8.7% of sites, while pondweed (three *Potamogeton* species submerged aquatic) and water purslane (*Ludwigia palustris* emergent) were found at 5.5% of sites. Because of the synoptic nature of the Survey (plant communities were sampled only one time), many plant taxa could not be identified to species because flowering parts and other key identifiers were not apparent. As a result, we were not able to determine whether rare species were collected during the Survey.

Aquatic vegetation in streams typically occurs in dense, monospecific patches that vary according to flow regime and shading (Butcher 1933). Shading is particularly important, and streams with substantial shading may not receive enough light to allow aquatic vegetation growth regardless of the water or substrate quality (Simonson et al. 1994). The Survey revealed that streams with 20% shading or less had an average of 1.6 species per site, whereas streams with greater than 80% shading averaged less than 0.25 species per site (Figure 4-27). As 95% of Maryland was once forested, it is likely that, with the exception of beaver impoundments, more aquatic vegetation exists in Maryland’s non-tidal streams today than prior to European settlement.

As expected, aquatic vegetation was far more widespread in Coastal Plain basins (Figure 4-28). Within the Coastal Plain, the Choptank and Pocomoke basins had the highest mean number of species per site (2.4). The difference in abundance and diversity between regions is likely a result of lower water velocities in Coastal Plain streams, but the extensive network of ditched streams with little or no canopy probably played a role as well. Taxa richness was higher in large streams than small (and theoretically more shaded) streams in the Coastal Plain (Figure 4-29). In contrast, there was no apparent relationship between taxa richness and stream size in the non-Coastal Plain, possibly because their requirements for soft substrates and slow stream flows are not met in higher gradient streams.

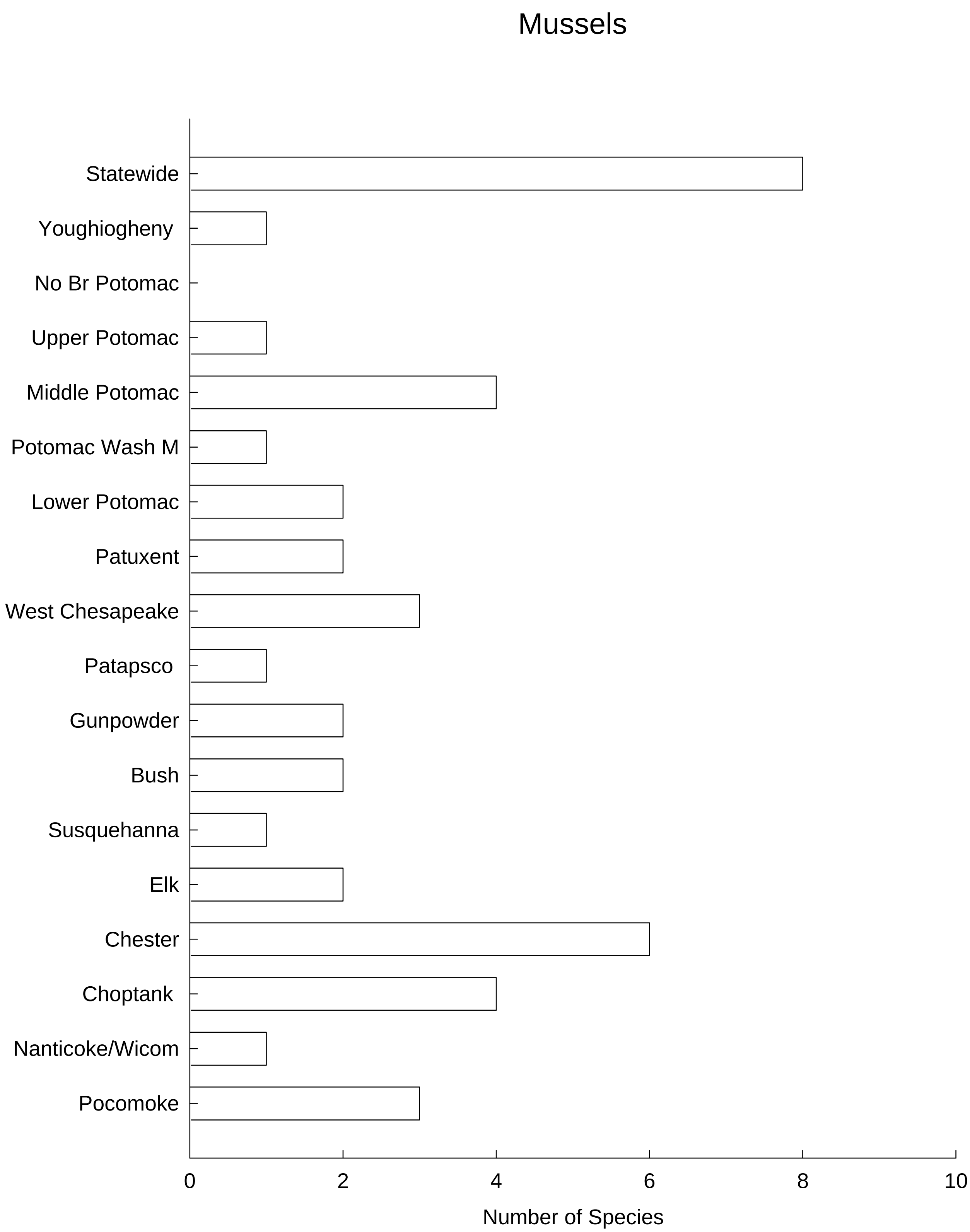


Figure 4-25. Number of mussel species, statewide and for basins sampled in the 1995-1997 MBSS

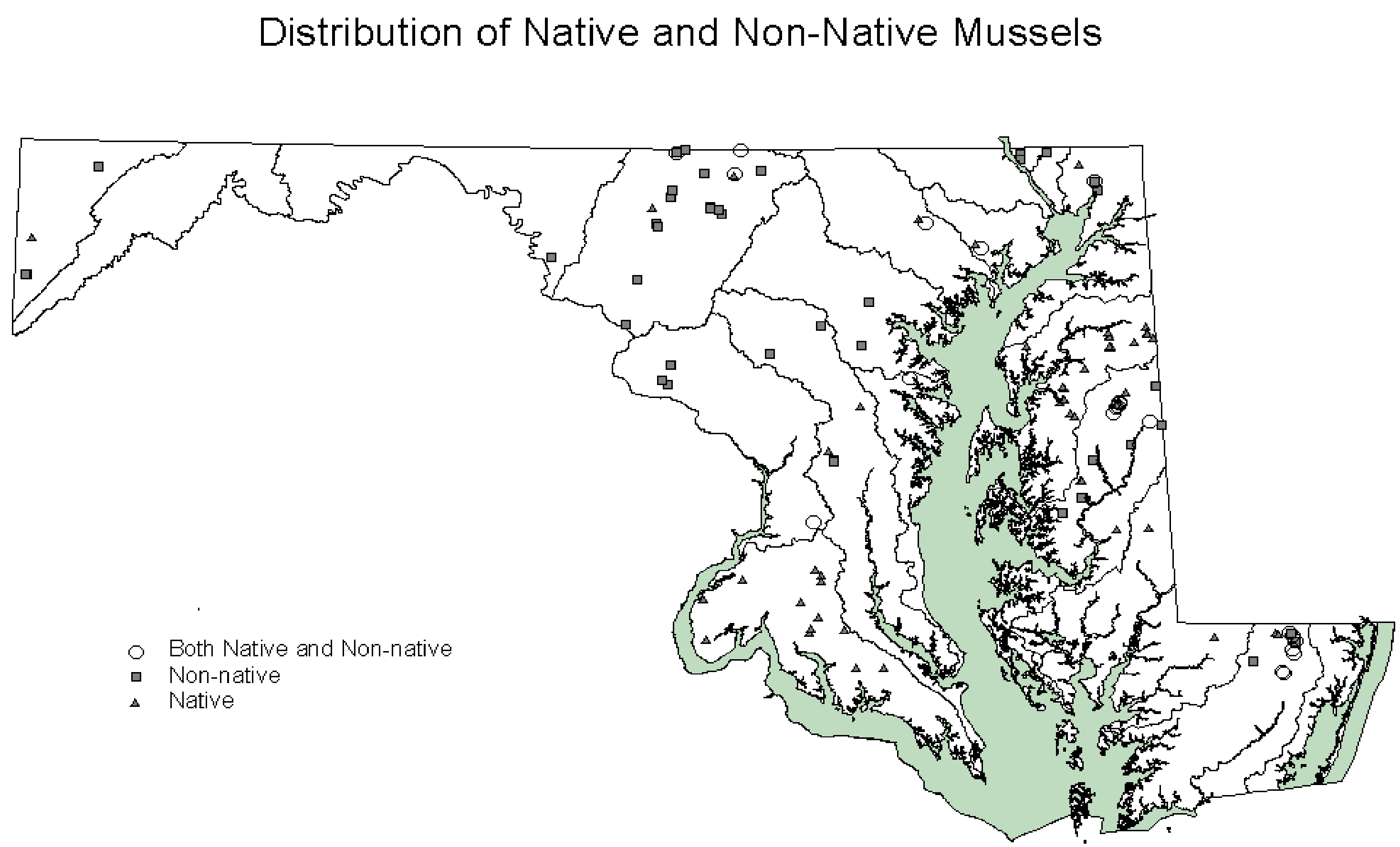


Figure 4-26. Distribution of native and non-native mussels species recorded in the 1995-1997 MBSS. Native refers to unionid mussels native to Maryland. Non-native indicates the presence of Asiatic clam (*Corbicula fluminea*).

Table 4-15. Aquatic plant species present by basin for the 1995-1997 MBSS

	Youghiogheny	North Branch Potomac	Upper Potomac	Middle Potomac	Potomac Washingtion Metro	Lower Potomac	Patuxent	West Chesapeake	Patapsco	Gunpowder	Bush	Susquehanna	Elk	Chester	Choptank	Nanticoke/Wicomico	Pocomoke
Submerged																	
Larger water-starwort									X					X		X	
Coontail														X	X		
Elodea	X			X					X	X	X	X					
Hydrilla															X		
Eurasian watermilfoil											X						
Naiad						X					X				X		
Riverweed													X		X		
Curly pondweed					X		X			X	X	X	X				
Floating pondweed	X				X		X	X	X					X	X	X	X
Small pondweed				X			X					X					
Water celery								X					X		X		X
Horned pondweed					X												
Emergent																	
Common water plantain						X	X		X								
Water pennywort													X	X	X		
Water purslane								X						X	X		X
Watercress				X			X		X			X					
Arrow arum				X	X	X	X										X
Pickerel weed						X											
Arrow head				X													
Lizard's tail								X					X		X		X
Burreed	X			X	X	X	X	X	X	X	X		X	X	X	X	X
Cattail			X				X								X		
Floating																	
Duckweed			X					X		X					X		X
Yellow water lily						X		X									X

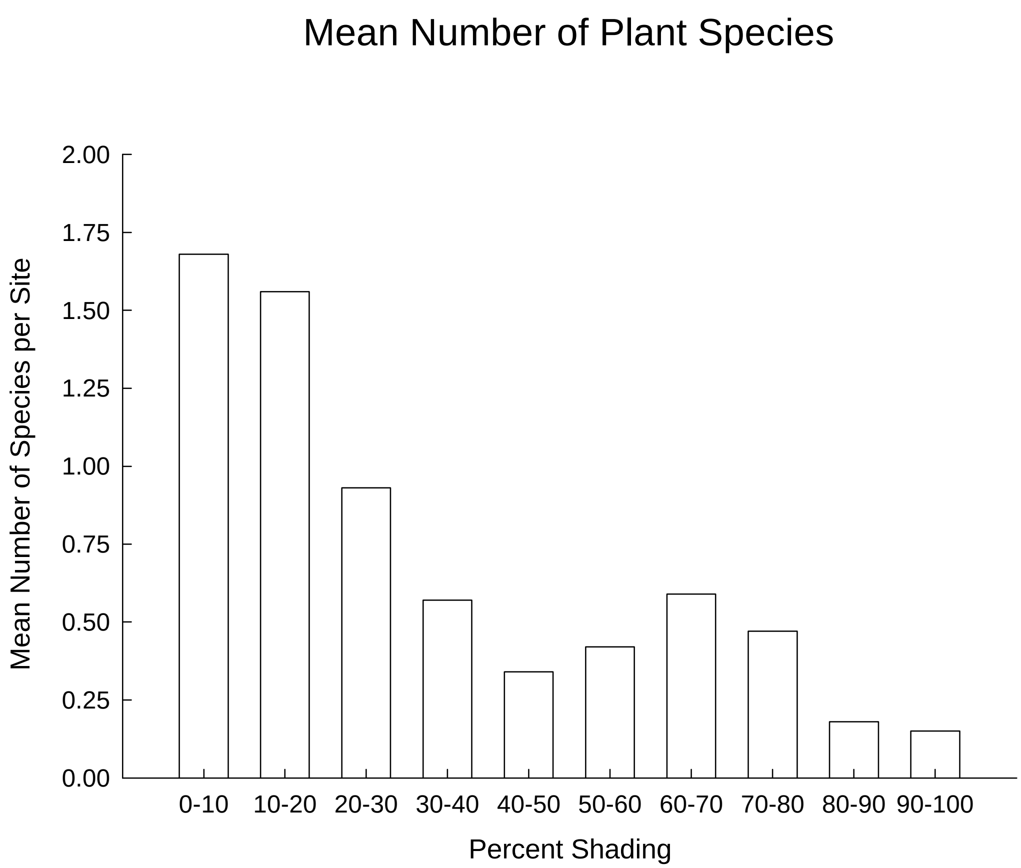


Figure 4-27. Mean number of aquatic plant species per site based on the percent shading received at each site for the 1995-1997 MBSS

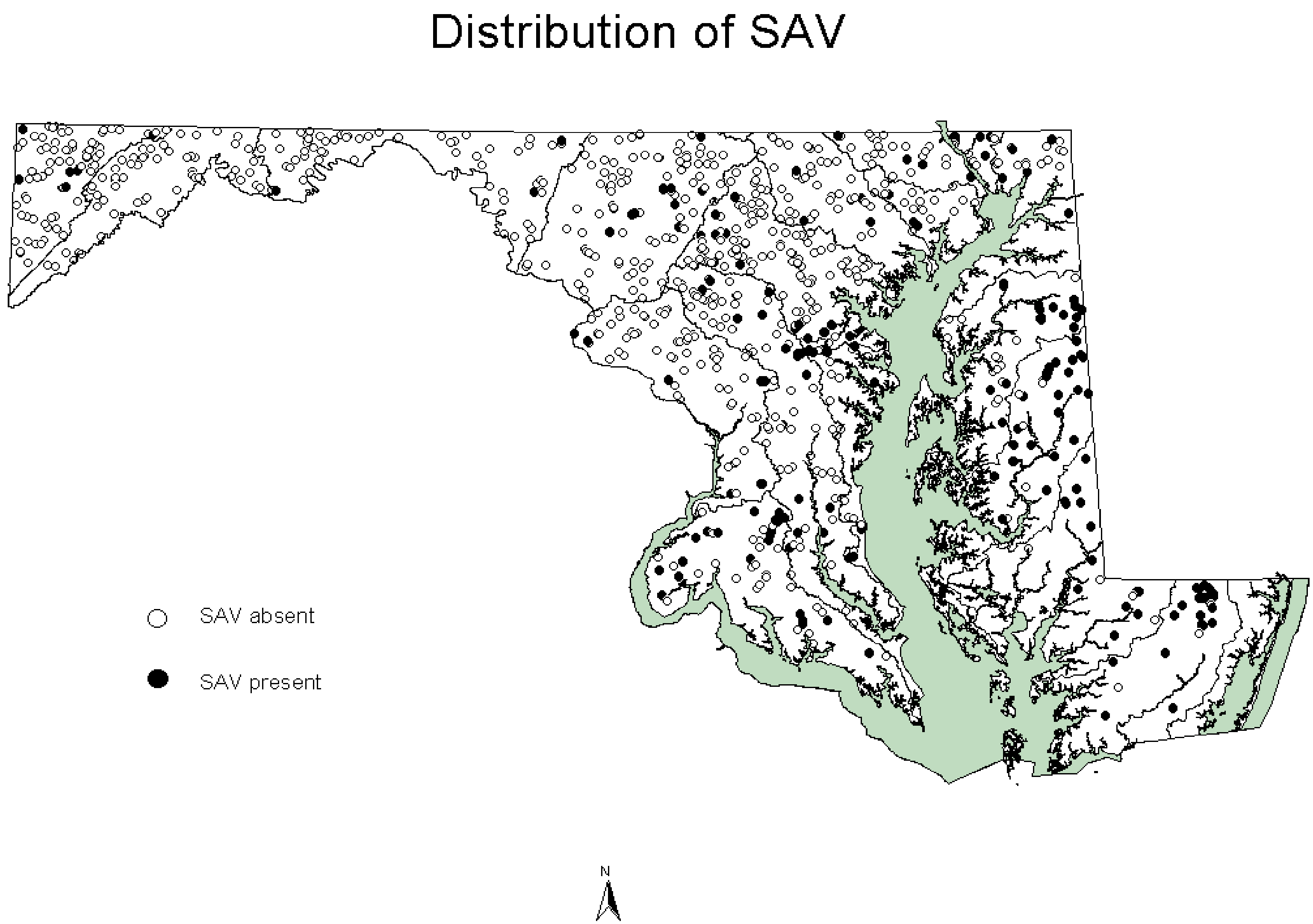


Figure 4-28. Distribution of submerged aquatic vegetation recorded the 1995-1997 MBSS

Figure 4-29. Mean number of aquatic plant species per site, by stream order, for Coastal Plain and non-Coastal Plain sites in the 1995-1997 MBSS